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MAN, MICROBE AND MALADY

DR. JOHN DREW

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MAN, MICROBE, AND MALADY

BY

DR. JOHN DREW

This is a book written by a bacteriologist primarily for laymen, but it is sufficiently detailed to be of interest also to medical students and general practitioners. It describes the various kinds of bacteria which are known to produce disease, the conditions in which they live and multiply, how they invade the tissues, and how the human body is normally equipped to resist them. It explains the ordinary precautions which should be taken by individuals and by the community to combat infection, and the use of such preparations as vaccines, serums and anti-toxins in the prevention and cure of bacterial disease. It considers also the possible employment of bacteria as a weapon of warfare, and the reasons for thinking that any attempts of this kind will be entirely ineffective.

THE AUTHOR

After serving in the Royal Navy during the war of 1914–18, Dr. Drew studied Medicine at an English University. He obtained his Degree and then spent some time on the Staff of a large Venereal Diseases Clinic, during which time he took his Diploma in Public Health. He then decided to devote himself to the study of the Science of Bacteriology, more especially in its relations to Medicine. He has served as Bacteriologist to a large General Hospital, as Bacteriologist in charge of a large Public Health Laboratory, and as a teacher on the Staff of a University. These appointments have brought him into active and intimate contact with the many problems connected with the bacterial diseases of man, and have given him—over the past fifteen years—a wide experience that has, in turn, provided him with the material for this book.

PUBLISHER'S NOTE

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To
MY WIFE

PREFACE

THIS book has been written in the hope that it may be of some interest and value to members of the general public. It is not intended to be a treatise on Applied Bacteriology, and it has not been designed as a pocket manual for the practitioners and students of Medicine or Bacteriology. I shall be well content if it interests some of my fellow-countrymen who do not possess any medical or bacteriological knowledge and experience, and gives them a measure of understanding of some of the problems connected with human bacterial disease. In their relation to human life and progress, germs are of more importance for what they do than for what they are, a fact that is too often ignored by academic bacteriologists. In this book, therefore, I have tried to focus the reader's attention upon the activities of germs and have written as little as possible about the germs themselves. Nevertheless, the reader must be in possession of some information about the biological characters of the germs themselves before he can appreciate their activities in relation to human disease. The first six chapters have been written to supply this essential information. They may possibly make rather dry reading, but their assimilation is necessary for a proper understanding of the rest of the subject-matter of the book.

The opinions expressed in this book are mine, and I offer no apology for them. I do not assert that they are faultless, but they are founded upon many years of experience and observation. Some of them may be unacceptable to some readers, but I shall continue to hold them until I have proof that they are faulty. In the absence of such proof, destructive criticism of these opinions is merely an expression of an opinion that is neither more nor less fallible than my own.

The subject-matter has been collected from a variety of sources—text-books, manuals, treatises, monographs, and papers—that are accessible to the medical profession but not to the general public. I have availed myself freely of the knowledge, experience, and industry of other medical bacteriologists, but I have not compiled a bibliography, or given a list of references, because most of my readers will be unable to utilize either

the one or the other. I wish, however, to acknowledge my especial indebtedness to the following sources: *A System of Bacteriology*, Medical Research Council, 1929–31; *The Principles of Bacteriology and Immunology*, Topley, W. W. C., and Wilson, G. H.; *The Examination of Water and Water Supplies*, Thresh, J. C., Beale, J. F., and Suckling, E. V.; *Bacteriological Grading of Milk*, Medical Research Council; *Recent Advances in Allergy*, Bray, G. W.; *The British Encyclopædia of Medical Practice*, Rolleston, Sir Humphrey, Bt., and Nos. 1A, 2, 3, and 5 of the excellent series of little monographs about injurious insects published by the Trustees of the British Museum (Natural History). The authors of these monographs are, respectively, Major E. E. Austen, J. Waterston, and B. F. Cummings.

I also desire to apologize for my failure to include in the list of my acknowledgments the sources from which I have copied Figs. 3 and 5, and which I am now unable to trace.

The illustrations are reproductions of original photomicrographs. All except Plate VI were photographed at a magnification of approximately 1000 diameters, but the original negatives have been considerably enlarged to facilitate reproduction. Plate VI was photographed at a magnification of about 100 diameters. For those readers who are interested in the size of bacteria, I might mention that the average size of a streptococcus (*i.e.*, one of the spheroidal units composing the chains in Plate VII) is 0·5–0·75 of a micron. A micron is the standard unit of bacterial measurement and is equivalent to 1-1000th of a millimetre.

INTRODUCTION

EVERYONE is familiar with representatives of the two great forms of life, the Animal and the Vegetable, that inhabit the earth; but only the trained worker with the microscope is familiar with a third form of life—comprising the Bacteria, the microscopic Fungi, and the Ultramicroscopic Viruses—that is also present on this planet. The Bacteria, with which this book is chiefly concerned, cannot be seen as individuals by the unaided human eye, but they are visible as a "colony" when a sufficient number of individuals is gathered together into a compact mass. In number they far exceed the aggregate of all the animals and plants, and they are more evenly and widely distributed in the soil, in dust, in water (both fresh and salt), in the air, on vegetation, and on the body surfaces, and in the external body cavities, of man, animals, reptiles, birds, fishes, and insects.

Directly and indirectly, the members of this third form of life exert a profound influence upon the economic activities and the well-being of man, and some of them play a decisive part in the causation of human disease. From the cradle to the grave, man is surrounded in all his activities, and wherever he may be, by multitudes of these microscopic forms of life, and he carries enormous numbers about with him under normal conditions of health and hygiene. Fortunately, only a few of these "germs" are able to cause human disease, and against these the healthy human body is equipped with defensive mechanisms that are only occasionally overthrown by the microscopic invaders.

In a highly civilized country, situated in a temperate zone, such as England, the Bacteria are probably more important incitants of human disease than the Ultramicroscopic Viruses, although these are responsible for many serious infections of man. They require, however, separate consideration, and this book will therefore be confined to a consideration of some of those bacteria that may be agents of human disease in Great Britain. The purpose of this book is to explain simply, and with the introduction of as few technical terms as possible, the means by which bacteria (germs) enter the human body and set up disease processes within it, the ways by which these germs are disseminated among human communities, and the methods by

which the healthy human body defends itself against their attacks. Mention will also be made of the precautions that can be taken by individuals and by communities to safeguard people against widespread (epidemic) bacterial disease.

Before these processes can be described in an understandable form, however, the reader must be in possession of some general information about the Bacteria, and about certain of the normal functions and activities of the tissues composing the healthy human body. The opening chapters have therefore been designed to supply this fundamental information.

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MAN, MICROBE, AND MALADY

CHAPTER I

THE CLASSIFICATION OF BACTERIA

PROTOPLASM is the essential stuff of which all living matter is made, and bacteria are simply minute specks of protoplasm, each speck being surrounded by a delicate, semi-permeable envelope. This simplicity of structure is correlated with a simple mode of life, a simple manner of reproduction, and a complete freedom from all those instincts, inhibitions, reflexes, urges, repressions, obsessions, and conventions that make the lives of multi-cellular animals, especially man, so complex and so difficult. The essential simplicity of the bacteria also confers upon them an extraordinary capacity of adaptation to changing conditions of life, a capacity that far exceeds any similar power possessed by animals and plants. Although they are so simple, they are nevertheless true living things, exhibiting the four cardinal signs of life: growth, reproduction, respiration, and the assimilation of food. Moreover, in common with other forms of life, they show variations in behaviour and in appearance under varying conditions of nutrition and environment.

Growth is manifested by an increase in the size of the individual bacterial cell—the bacteria are all one-celled (unicellular) organisms—but this increase is only of microscopic proportions under the best conditions. No bacterial cell ever grows big enough to be seen by the unaided human eye.

Reproduction is effected by a simple division, or fission, of the cell into two identical descendant cells. The bacteria are entirely asexual, and reproduction is largely determined by external factors such as temperature, moisture, oxygen, and food supply. In a sense they are immortal because, given suitable environmental conditions and an inexhaustible food supply, a single bacterial cell could multiply itself to infinity. Fortunately such conditions can never arise naturally, because the progeny of a

single cell would soon attain to a mass of matter large enough to crowd all other forms of life off this earth. Nature provides many efficient checks against excessive bacterial multiplication. Under artificial conditions in the laboratory it is possible to provide bacteria for a limited time with optimum conditions for their multiplication, and experiments have shown that many species will begin to divide within half-an-hour and will continue to double their number at this rate until their food supply is exhausted, or until they are poisoned by the accumulated waste products of their own life activities. In this respect again, bacteria resemble other forms of life, including man, because human beings can poison themselves with the waste products of their tissue activity. If, for example, the kidneys cease to function and fail to excrete the waste products of our metabolism in the form of urine, we rapidly sink into a coma and die.

Respiration is effected by a simple interchange of oxygen between the semi-fluid contents of the cell and the surrounding atmosphere. All bacteria require oxygen for the maintenance of their vital processes, and a bacterial cell that is completely deprived of oxygen soon dies. Species differ, however, in their oxygen requirements, and these differences enable us to group the known bacteria into three categories :—

1. Obligate Aërobes (or Aërobic Bacteria);
2. Obligate Anaërobes (or Anaërobic Bacteria), and
3. Facultative Bacteria.

The obligate aërobes comprise those bacteria that must live in an atmosphere containing free oxygen—*i.e.*, the atmosphere that we breathe. A slight reduction of the oxygen content of the surrounding atmosphere prevents these bacteria from multiplying, and removal of the free oxygen is rapidly fatal to them.

The anaërobic bacteria, on the other hand, cannot develop in an atmosphere that contains even a trace of free oxygen. Some of the more delicate members of this group are rapidly destroyed in their vegetative state by free oxygen; others are able to assume a dormant condition in which their vital processes are conserved for varying periods of time. The anaërobes obtain the oxygen, which is just as essential for their life processes as for those of the aërobes, by the decomposition of organic matter, all of which contains oxygen. The final stages of putrefaction, which is Nature's method of disposing of the dead animal body, are brought about by the activities of anaërobic bacteria that break

down the complex organic constituents of the body in their search for oxygen.

The majority of bacteria are, however, facultative organisms—*i.e.*, they can live either under aërobic or under anaërobic conditions—although each species has its preference for the one mode of respiration.

The assimilation of food is effected by the absorption of nutritive matter in a fluid state through the semi-permeable cell envelope. Bacteria can only utilize relatively simple chemical substances for their food, and these substances are often obtained by the decomposition of complex compounds, so that bacteria are responsible for the initiation and maintenance of many complicated chemical reactions. The necessary breaking down of the complex organic and inorganic substances is commonly performed by peculiar chemical substances, known as enzymes or ferments, that are manufactured by the bacterial cell. There are many of these bacterial ferments now known to us and many others that are still unknown. Some of these ferments are common to many different species of bacteria; others are exclusive to particular species or groups of species. The human body manufactures many ferments for its own purposes, notably the peptic ferment in the stomach, which is essential for the proper digestion of our food, and the starch-splitting ferment, diastase, which is essential for the proper metabolism of sugar, a substance that is of vital importance for the maintenance of the energy of our tissues. The manufacture of junket—a Devonshire delicacy with which many readers will be familiar—from cow's milk is effected by ferment action, and the results of bacterial ferment action are often more profound than the alteration of milk to junket. Sometimes the products of bacterial ferment action are poisonous for animals or plants; sometimes they are poisonous for the bacteria themselves. In connexion with human disease, the bacterial ferments that split and liquefy proteins (proteolytic ferments), and those that attack sugars (saccharolytic ferments), are probably the most important, because the tissues of the human body are largely composed of proteins and every cell in the body requires sugar as its source of energy. The characteristic feature of all ferments, whatever their origin, is that they initiate chemical reactions between substances without entering into the reactions themselves. A minute quantity of a ferment is therefore sufficient to bring about a long and complicated chemical reaction. Man is now beginning to utilize bacterial

ferments in agriculture and industry to obtain, simply and cheaply, chemical reactions that would otherwise be prohibitively expensive, or even impossible, by ordinary chemical methods.

When bacteria are studied under the microscope, three basic cell forms are encountered among the different species. These are:—

1. The Sphere;
2. The Cylinder, and
3. The Spiral.

The spherical bacteria, tiny balls of protoplasm, are known as cocci (pronounced kokki; singular coccus). The cylindrical bacteria, tiny rods of protoplasm, are known as bacilli (pronounced bassilli; singular bacillus). The spiral bacteria are known as spirilla (singular spirillum), spirochætes, or spirochætæ (pronounced spirokeety; singular spirochæte). These forms are apparently immutable. No one has yet been able to change one into another, or has ever witnessed such a change either under natural or under artificial conditions of development. Variations of the basic form are, however, often encountered. The sphere may be flattened on one side, or slightly indented, or elongated to form an ovoid cell; but invariably any one axis of the cell is approximately equal to any other. The cylinder may be short and thick, or long and thin; but invariably the long axis is definitely longer than the transverse axis. The spiral organism may have close, tightly-wound spirals like a fine screw, or loose, undulating curves like the permanent wave seen on so many feminine heads nowadays. It may show only a single curvature, like a boomerang, or it may show multiple curves and twists; but invariably it is a slender, curved rod or filament. These basic forms are of great value in the identification of different groups and species, especially those species that are responsible for human disease.

The majority of the known bacteria are incapable of independent locomotion; they depend for their dispersal upon transport by air or water currents, or upon carriage as lodgers, or parasites, in the body cavities and on the body surfaces of their human and animal hosts. Some species are, however, capable of independent movement in a fluid medium, but only in a fluid medium. These motile bacteria are provided with tiny threads (known as flagella), which project from the cell envelope and by

their vigorous lashing movements propel the cell through the fluid. The power of independent movement is not of much importance as a means of dispersal under natural conditions, but it is of value in the laboratory identification and differentiation of species.

Some species of bacilli form spores. The bacterial spore is a spherical or oval body that is provided with a tough, resistant envelope. It is formed within the bacillary cell and contains all the vital matter that was present in the vegetative cell. When the spore is mature it is set free by the disintegration of the envelope of the parent cell. Spore formation among the bacteria is confined to the bacilli, and is a special defensive mechanism designed to preserve the bacterium from the action of antagonistic agencies that would kill the vegetative (*i.e.*, the actively growing and multiplying) cell. Bacterial spores are the most resistant forms of life known to us; some of them can withstand boiling for several hours, and most of them are highly resistant to strong disinfectants and other germ-destroying (germicidal) agencies. When a spore-forming bacillus is also pathogenic for man, the resistant spore phase introduces important problems in the protection of human beings, because the spores can remain viable in soil, dust, water, milk, foodstuffs, and on vegetation for months or even years, and they can be widely dispersed in wind-blown dust. The chief danger of the anaërobic bacilli that are responsible for the human diseases of tetanus (or lock-jaw) and gas gangrene is that they form highly resistant spores that can survive the ordinary methods of disinfection and sterilization. When a bacterial spore is deposited in a suitable environment it germinates into the bacillus, which then proceeds to multiply, secrete its ferments, and manufacture its poisons.

Many species of bacteria are able to surround the cell with a thick, protective coat, or capsule, under certain conditions. This capsule, which is of a gelatinous or gummy nature, is an active secretion of the cell and is not formed from the materials surrounding the bacterium. Capsule formation is another special defensive mechanism elaborated by the bacterial cell to protect it from destructive agencies. There are certain human pathogens that constantly form capsules when they enter the body-tissues, and these capsulated bacteria are much more difficult to destroy than are similar bacteria that do not form capsules.

Although bacteria are unicellular organisms with a very simple

structure, the chemical constitution of the individual cell is quite as complex as that of a cell of the human body, which is composed of millions of microscopic cells, each of which is a tiny laboratory in which complicated chemical reactions are continuously being performed during the lifetime of the individual. The chemical composition of the cell differs somewhat in the different species of bacteria, but certain basic organic and inorganic substances are common to all species, and all bacterial cells are built up on a foundation of proteins, which are themselves complex organic substances. Most of these bacterial proteins are foreign to the human body; some are poisonous to it, and many can function as *antigens* when they are introduced into the tissues of the human body. An antigen may be defined as any substance which, when injected into the body-tissues of an animal (including man), stimulates the production by the tissues of a specific antibody and which, when mixed with this antibody, reacts with it in some observable way. Each species of bacterium has its own peculiar antigens, which are specific to that species. In addition, closely related species possess one or more antigens that are common to the group and, finally, there are some antigens that are widely distributed among many species. Every bacterial cell therefore possesses a complex antigenic constitution which includes specific and group antigens. Bacterial antigens are extremely important factors in the evolution of bacterial disease in man, in the evolution of the resistant state in the individual attacked, and in the laboratory diagnosis of many bacterial diseases of man. They are not substances manufactured by the bacterial cell, but are part and parcel of the living protoplasm of which the cell is constituted.

The antibodies that are evoked in response to antigenic stimulation are similarly multiple, because each antibody is highly specific for its homologous (*i.e.*, of similar structure) antigen, and usually exerts little, if any, action upon other antigens.

Bacteria show many other interesting features, but a description of these is not pertinent here. The characters of oxygen consumption, motility, enzyme production, spore formation, capsule formation, and antigenic constitution are the important ones for the appreciation of the vital activities of the pathogenic bacteria and their relation to human disease.

A study of bacterial activities in relation to human health reveals that the bacteria may roughly be divided into three groups :—

1. Those whose activities are directly or indirectly beneficial to man.
2. Those whose activities are neither beneficial nor harmful to man.
3. Those whose activities are directly or indirectly harmful to man.

The organisms in the first two groups are Saprophytes (or Saprophytic Bacteria), *i.e.*, they are able to lead a free-living existence in nature, obtaining their food supply by the decomposition of inanimate organic and inorganic matter. The organisms in the third group are Pathogens (or Pathogenic Bacteria), and are potentially capable of causing disease in man, animals, and plants. The saprophytes can be subdivided into (*a*) obligate saprophytes, and (*b*) facultative pathogens. The obligate saprophytes are unable to cause disease in animals or plants under any circumstances. The facultative pathogens normally lead a free-living existence, but they are able to cause disease under certain circumstances. The pathogens can similarly be subdivided into (*a*) obligate pathogens, or parasites, and (*b*) facultative saprophytes. The obligate pathogens are true parasites of animals and/or plants and can only live and multiply in the living tissues of their animal or vegetable hosts. Some of them can survive for variable periods of time outside the body of the host under favourable conditions, but many of them die rapidly. The facultative saprophytes prefer to live a parasitic existence in the bodies of animals and plants, but they are capable of prolonged survival and, under favourable conditions, even of active multiplication as saprophytes outside the bodies of their hosts. The great majority of the known bacteria are obligate saprophytes; a small number are either facultative saprophytes or facultative pathogens, and a very few—relative to the enormous number of known species—are obligate pathogens.

The popular usage of the term, " germ ", is so firmly associated with the idea of disease that it is difficult for the layman to appreciate that the beneficial activities of bacteria far outweigh their harmful activities. Indeed, if it were not for the beneficial activities of certain soil bacteria and fungi (about which the reader can read in another book in the Penguin Library),* it is doubtful whether there could be any growth of vegetation as we

* " Microbes by the Million ", by Dr. H. Nicol.

know it on this planet. All animal life is ultimately dependent upon vegetable life for its maintenance, and man is dependent upon his flocks, his herds, and his crops. When their crops fail, human communities are rapidly decimated by famine and pestilence, and the absence of edible plants is incompatible with the presence of human life.

The beneficial activities of bacteria are very numerous. We are, at present, conversant with only a few of them, yet these add enormously to our comfort and well-being. Many important industrial processes, including the Dairy Industry, are largely dependent upon the activities of bacteria and microscopic fungi. The ripening of butter and cheese, the tanning of leather, the curing of tobacco, the retting of flax, the manufacture of alcoholic beverages and of vinegar, and the production of enzymes that are of value in Medicine and Industry, are some of these activities. Man has only very recently begun to utilize the controlled activities of bacteria for his own benefit, and there is little doubt that in course of time, and with increasing knowledge, these controlled bacterial activities will exert a far-reaching influence upon the speed and extent of human progress. Our continued existence as a race is largely dependent upon the beneficial activities of bacteria: the individual is continually threatened by their harmful activities.

The harmful activities of bacteria are unfortunately not confined to their direct attack on man. Indeed, such direct action is of comparatively little importance when weighed against the indirect harm they do to us by their ravages among our food animals and plants, and the colossal economic losses they annually inflict upon us. The course of human history has been completely altered on numerous occasions in the past by the microbial destruction of human food supplies. In 1845, the disease of potato blight, which is caused by a microscopic fungus, destroyed the Irish potato crop and directly precipitated the terrible famine of 1845–46. The suffering was intense and, in spite of the most generous governmental and private aid, a quarter of a million Irish people, out of a total population of some eight millions, died of hunger or of disease superimposed upon starvation. The famine had such profound results on the political history of the British Isles that Disraeli remarked that the disease of a single tuber had altered the whole course of our history.

The effects of all microbial diseases of plants are neither so

dramatic nor so disastrous as the example I have given; but they cause a steady and a world-wide loss which, if it could be accurately computed, would reach astronomical figures. The losses due to the downy mildew disease of the vine alone have been estimated at £500,000,000 annually. It is no exaggeration to say that man's existence on earth is only secured by a ceaseless vigilance and a continuous struggle against the microbial agencies that destroy his food plants. The public knows little about this perpetual warfare, and it is commonly assumed that diseases of crops are the concern of the farmer alone. It is the consumer, however, who ultimately pays for the toll taken by these diseases, and the townsman is therefore directly concerned with the devastation wrought among the plants upon which he depends for food, shelter, and clothing. It has been calculated, for example, that for every two potatoes he buys he pays for a third lost by disease, and in every six cotton shirts the cost of a seventh is included. Estimates made by the plant disease survey of the U.S.A. Department of Agriculture indicate that approximately 1 bean in every 12, 1 apple in every 7, 1 peach in every 8, 1 bushel of potatoes in every 12, and 1 bushel of wheat in every 10, are destroyed annually by microbial disease. In a country like England, which is forced to import the bulk of its food supplies, the annual losses from disease among our food plants impose an enormous financial burden upon the nation, and are directly responsible for much of the undernourishment of the poorer classes of our population that is now exercising the attention of our Health Services.

Microbial diseases of man's food and economic animals are only less important than those of his economic and food plants because, while it is true that man can live on a purely vegetarian diet, he is naturally an omnivorous animal, and most human communities require a certain proportion of animal flesh in their diet for their proper sustenance. The complete absence of animal proteins and fats from the diet would undoubtedly have a serious effect upon mankind, although some individuals and communities would suffer more than others. A big reduction in man's supply of transport and draught animals may also have serious consequences, because, even in this mechanical age, we are dependent to a considerable extent upon our beasts of burden. There are still parts of the Earth where the essential transport of food and other supplies can only be economically performed by animals that are inured to the peculiar climatic

conditions prevailing in those regions. The camel in the Central Asian deserts, the yak on the Himalayan plateau, and the llama in the Andean valleys, are essential beasts of burden whose value to man will probably never be economically challenged by mechanical means.

Man is also directly concerned with some of the microbial diseases of that group of the lower animals known as the vermin. The most dangerous of these animals are the rat, the mouse, and the rabbit, but other species of rodents are also a serious menace to us. These animals spread and transmit to man a number of the most serious microbial diseases to which the human organism is susceptible. In addition, by their destruction of our cultivated food-plants, and by their spoilage of our stored food supplies, they cause enormous economic losses that are of grave significance. Many species of "insects", notably the blood-sucking flies—such as the mosquitoes—and the ecto-parasites of man, such as the louse, the bed-bug, and the flea, also transmit to man and disseminate numerous grave microbial diseases. The most dangerous insect in the British Isles, and one that is a very serious pest, is, however, the common house-fly. It is a common vector (*i.e.*, transporter) of pathogenic bacteria, and its filthy feeding habits ensure that any foodstuffs exposed to its visitation will be liable to dangerous contamination with pathogenic microbes.

CHAPTER II

THE WEAPONS OF BACTERIA

ALTHOUGH microbial disease of our food animals and plants is indirectly a graver menace to us as a race than the direct attack of bacteria upon us as individuals, the individual is naturally more concerned about his own affairs than about those of the race. The former are continually exercising his thoughts and influencing his actions; the latter are largely relegated to the attention of posterity. This attitude towards disease is not surprising, because it is impossible for any individual to survive the normal span of human life without suffering from some bacterial infection. The modern tendency for men to crowd together into towns and cities, modern education, modern pleasures, and the growth of means of transport and communication, increase the individual's chances of contracting

bacterial diseases. Other features of modern civilization protect the individual from bacterial attack; but, in general, the bigger the crowd the greater the risk. Urban populations suffer more than rural populations from bacterial diseases, and a densely populated land has a higher general incidence than a sparsely populated one. The reasons for this unequal distribution will be discernible later; but the fact of the distribution is mentioned here because it explains the natural interest in, and apprehension about, germs and the diseases they cause among the inhabitants of these islands.

The pathogenic bacteria produce their manifestations of disease either (*a*) by their invasion of the body-tissues or (*b*) by making poisons that destroy the tissues. Probably every case of bacterial invasion is associated with some degree of local poisoning of the tissues, and many pathogens combine the two methods, but there are some that are devoid of invasive power. By invasion we mean the power to multiply at the original site of infection, to spread from that focus—either by a direct growth into the surrounding tissues, or by carriage along the normal channels in the tissues—and to become generally dispersed throughout the body. Before it can multiply at the initial site, a bacterium must first break down the local defences of the tissues. These are overcome by ferment action, by mechanical interference with their functions, by the production of poisons that paralyse and destroy their constituent cells, and by the liberation of antigens from the dead bacterial cells. These antigens combine with the corresponding antibodies made by the tissue-cells and so protect the living bacteria from their antagonistic action. The following illustration may help the reader to understand the phenomenon of bacterial invasion.

There is a deadly disease of cattle and other domestic animals, caused by an aërobic, spore-forming bacillus—known as *B. anthracis*—that is transmissible to man. Human anthrax is chiefly an occupational disease, confined to those people who work among the domestic animals or their products, such as skins, hides, and wool. When the spore of *B. anthracis* lodges in a minute abrasion in the human skin, it germinates and the vegetative cell commences to multiply rapidly by fission. As this multiplication progresses, the surrounding tissues are killed and broken down and the tiny channels in them are filled with plugs of bacilli. The destruction of the tissue-cells and the death of many of the bacilli result in the liberation of poisonous

decomposition products. These are absorbed by the surrounding healthy tissues and poison them. Some of these decomposition products also enter the blood-stream and are carried all over the body, thus undermining the general resistance of the individual. The lowering of the local and general resistance in turn permits of a wider invasion of the tissues by the bacillus. Sooner or later a blood-vessel is involved in the local destructive process and the bacilli enter the blood-stream, in which they multiply rapidly and are dispersed all over the body. Active multiplication continues at any points where the bacilli may be arrested in the minute blood-vessels that ramify in the various organs of the body, and when the delicate vessel wall bursts on account of the increasing distension produced by the growing plug of bacilli, the organisms are projected into the surrounding tissues to continue their multiplication there. Eventually, if the proper treatment is not given, the individual dies from the mechanical interference with the functions of vital organs caused by the innumerable masses of bacilli. Anthrax provides us with the best example of a bacterial disease caused by a purely invasive bacterium because, up to the present, no one has been able to demonstrate the manufacture of any specific poisons by the anthrax bacillus.

Diphtheria is a good example of a human disease caused by a purely poisonous bacterium. The causal bacillus, *B. diphtheriæ*, can only multiply locally on the surface of the body, the commonest site for this multiplication being the surface of the tonsil. It never penetrates into the underlying tissues or enters the blood-stream; but it makes a very powerful and specific poison, which diffuses out from the living bacillus and is absorbed by the cells of the underlying tissues. Many of these cells are destroyed, and the poison passes into the blood-stream and is dispersed all over the body. Certain cells in the brain and heart are peculiarly sensitive to the action of this poison, so that, when it is brought to them in their blood supply, they are either killed or paralysed. As these cells are responsible for the control of vital bodily functions, the individual dies if a sufficient number of them are detroyed by the diphtheria poison.

A poison, such as diphtheria, that is actively manufactured by a bacterium, is technically called a toxin, and two kinds of bacterial toxins are known, exotoxins and endotoxins. Exotoxins are specific poisonous products that diffuse out from

the living bacterial cells; endotoxins are specific poisonous products that are kept locked up in the living cells and are only liberated after their death and disintegration. Each species of toxin-forming pathogen makes its own specific toxin, or toxins, so that a large number of them are known to science and others still await discovery. Most of the human pathogens form endotoxins and are both invasive and toxic bacteria. A small number form both endo- and exotoxins, and a few form only exotoxins. Some of the exotoxin-forming bacteria possess no invasive powers; others are both toxic and invasive. Lobar pneumonia is an example of a human disease caused by an endotoxic and invasive bacterium; cholera, of a purely endotoxic bacterium without any invasive power, and puerperal sepsis (childbirth fever) of an exotoxic and invasive bacterium.

The ability of a germ to cause disease in a human being depends upon the final balance that is struck between the infective power of the germ on the one hand and the resistance of the individual on the other. If the balance tips over in favour of the bacterium, the result is disease; if it tips over in favour of the individual, there will be no manifestation of disease, but the individual may continue to harbour the germ for a time, during which he may unwittingly transfer it to other people who are less resistant and who manifest the disease. Successful repetition of this resistance often results in the individual acquiring an immunity against the germ, and repeated contacts with the same germ thereafter render the immune state permanent.

The infective power of any pathogenic bacterium depends upon the interplay of several factors, the most important of which are the virulence of the germ, the dose of the germ received by the individual, and the route by which it enters the body—*i.e.*, the portal of entry. The virulence of a germ is the summation of its invasive and toxic powers at any given moment in any particular host. Bacterial virulence is always a variable property and is subject to wide fluctuations over short periods of time. It is influenced by the environment and the food supply of the bacterium, and is governed by forces about which we possess little accurate knowledge at present. In general, however, the virulence of a pathogenic bacterium is exalted by its passage through a succession of suitable animal hosts—*i.e.*, by successful parasitism—but it cannot be exalted above a certain maximum that is constant for each species. This fact

is of great importance because, if the virulence of a bacterium could be exalted to an unlimited degree, a state would soon be reached in which the germ would inevitably exterminate the host species. As it is, no bacterial disease of man is known with an absolute 100 per cent. mortality rate; some individuals in the community that is attacked escape infection and others recover from the infection. Even plague, which is probably the deadliest of the epidemic bacterial diseases of man, cannot exterminate the human race, although on several occasions in the past it has come perilously near to that achievement. The terrible outbreak of plague in the fourteenth century, the Black Death, wiped out three-quarters of the population of Europe and completely altered the course of European history. Bacterial virulence is reduced by the action of many extraneous factors and is subject to cyclical changes that are independent of external influences. Failure to overcome the resistance of the host, exposure to unfavourable environmental conditions, and an insufficient or unsuitable food supply all reduce the virulence of a bacterium. Unsuccessful parasitism, which may be due to a progressive decline in its virulence or to a progressive increase in the resistance of the host species, results in the gradual eradication of the pathogen, which either dies out or adapts itself to a saprophytic existence. An example of this eradication of a pathogenic bacterium by natural processes is seen in the steady decline of tuberculosis among the inhabitants of the British Isles during the last half-century. Tuberculosis is still a serious disease in these islands, but its incidence and its mortality rate have declined so steadily that, if the process continues, the disease will practically disappear before many more generations have passed.

The dosage of the pathogen is often a determining factor in the infection of the individual, and the factors of virulence and dosage are closely inter-related. A small number of highly virulent germs is generally sufficient to cause disease in any but the most resistant host, whereas a large dose of germs of low virulence often fails to infect even the weakly and sensitive individual. Naturally, the liability to disease increases with every increase in the dose of a virulent germ and, if both dose and virulence are sufficiently high, the individual's defences will be overwhelmed and death may occur within a few hours of the onset of the infection.

The third factor of the portal of entry of the germ exercises

a decisive influence only in some of the bacterial diseases of man, but it exerts a modifying influence in others. Certain pathogenic bacteria are able to enter the human body and produce disease by any path of entry; others have a predilection for a particular tissue or organ of the body and can only produce their specific diseases when they are deposited at the proper site. For example, the causal agent of typhoid fever, *B. typhosus*, can only cause that disease when it enters the human body through the mouth in food or water. If it is rubbed into the skin, inoculated into wounds, or inhaled into the lungs, it cannot cause typhoid fever. The causal agent of the venereal disease of gonorrhœa must be deposited upon the surface of the delicate membrane lining the human genital tract, or upon the conjunctiva of the eye, in order to produce its specific disease. Numerous other similar examples could be given, but sufficient has been said to emphasize the importance of the portal of entry in the causation of bacterial diseases of man.

CHAPTER III

THE ENTRANCES AND EXITS OF THE HUMAN BODY

THE human body is composed of a vast number of cells of microscopic size, each of which is a tiny laboratory in which complicated chemical reactions are continuously in progress during the life of the cell. The human organism takes origin from a cell that is the product of the fusion of a male germ-cell from the testicle of the father with an egg-cell from the ovary of the mother. The fertilized human egg possesses the faculty of unlimited division, and the human body is built up by the repeated divisions of the cells derived from the initial division of the ovum. At an early stage in the evolution of the individual, groups of these cells become partially separated off from the main mass and develop into the different organs and tissues of the body, acquiring during this process specific characters and functions. The cellular structure of the human body controls the resistance of the body as a whole to bacterial disease, because an individual's resistance is the summation of his cellular resistance. It is the way in which the cells of our bodies respond to the stimulus of bacterial attack that determines our individual resistance.

The skin is a tissue with which everyone is familiar. It is a complex tissue, but we need not bother here about its minute structure. It will be sufficient for our purposes to note that it is plentifully supplied with tiny blood-vessels and nerves, and with tiny sweat- and grease-glands, and that certain areas of it are liberally supplied with hair-follicles. It is the blood coursing through the vessels in the surface layers of the skin that gives the pink colour to the healthy skin. Blushing results from a sudden influx of blood, caused by some emotional stimulus, into the blood-vessels in the skin of the face, and pallor results from the reverse process. The nerves provide us with our sensations of touch, temperature, and pain, and they regulate the action of the blood-vessels and of the glands in the skin. The sweat-glands assist in the excretion of waste products from the body, and the grease-glands keep the skin smooth and supple. These glands open on to the external surface of the skin through tiny ducts, the orifices of which can be seen under a good hand-lens. The hair-follicles are tiny pits in the skin that house the bulbs and a short portion of the shafts of the hairs. They are profusely scattered over some areas of the skin and are present in smaller numbers over most of the skin surface. The only regions that are always devoid of them in either sex are the palms of the hands, the soles of the feet, and a narrow strip down the inside of the thighs. Their numbers and their distribution differ in the two sexes, the male being normally much more hairy than the female, and to a lesser degree in different individuals of the same sex. The number of the hair-follicles tends to increase with advancing age in both sexes, but it does not follow necessarily that every follicle houses a hair. Indeed, the number of hairs is always considerably less than the number of hair-follicles, which is fortunate for some of us, who might otherwise be permanently partially hidden by a jungle growth.

The unbroken human skin presents an impassable barrier to most of the pathogenic bacteria; only a very few species can penetrate the intact skin. Any breach in the continuity of the skin surface may, however, enable bacteria to penetrate into the deeper, less-resistant tissues lying beneath the tough, horny, surface layer. Bacteria are so minute that these breaches need not be large enough to be seen by the naked eye, and trivial injuries that are never noticed by the individual are sufficient to produce them. The friction of tight-fitting or coarse-texture underclothing, gentle scratching, shaving, the impact of wind-

blown grit, and the innumerable slight bumps, pinches, and scrapes that our skin is continually receiving in the course of our daily life, are all injuries that lead to microscopic breaches through which bacteria can penetrate. Moreover, the orifices and ducts of the skin-glands, and the shafts of the hair-follicles, are natural portals of entry to the deeper layers of the skin. Serious bacterial infections of the skin are comparatively rare, however, in spite of all these aids to bacterial invasion and in spite of the fact that the skin is the most exposed of all our tissues to bacterial attack. When the skin is attacked it usually puts up a remarkably effective resistance and, as a rule, it only succumbs when the individual is under-nourished, or is in a low state of health, or after its resistance has been lowered by faulty treatment.

Most persons are familiar with the sight of human blood, but comparatively few are familiar with the composition and functions of this vitally important tissue of the body. It is quite correct to speak of the blood as a tissue, even though it normally exists in a fluid state, because, like all the other tissues of the body, it is composed of microscopic cells. It differs from the solid tissues only in the fact that its component cells are suspended in a fluid medium instead of being cemented together by a solid matrix. The red colour of the blood is derived from a pigment, known as hæmoglobin, that is contained in cells that are microscopic, bi-concave discs, each cell being virtually a sack full of hæmoglobin. These red blood corpuscles are the oxygen-carriers of the body, because the essential characteristic of hæmoglobin is its ability to enter into a loose chemical combination with the free oxygen in the atmosphere. As the tiny red corpuscles stream through the minute blood-vessels in the walls of the air-sacs in our lungs, whither they are propelled by the pumping action of our heart, they each pick up a minute quantity of oxygen from the air that we have drawn in to fill the air-spaces in our lungs. Carrying their load of oxygen, the red cells proceed on their circular tour around our body and, when they come into contact with tissue-cells that require the oxygen, they hand it over as they squeeze past in the minute blood-channels that ramify throughout all our tissues. The red cells of the blood do not take any direct part in the defence of the body against invading bacteria, but indirectly they are an essential element in the body's defences, because the activities of the tissue cells are dependent upon their oxygen supply. A reduced supply means diminished activity and lowered resistance.

There are other cells in our blood besides the red corpuscles, known as white corpuscles, or leucocytes (pronounced lewkosites), and these play a vitally important part in our resistance to bacterial attack. Their rôle is essentially that of policemen and scavengers. They wander along the minute blood-channels in our tissues, collecting any waste matter of a particulate nature that they encounter, such as fragments of dead tissue-cells, specks of foreign matter, and bacteria. The particles are either engulfed by the leucocytes and then digested, or else they are carried by the cells to some part of the body from which they can easily be ejected. The process by which the leucocytes ingest and then digest bacteria is technically called phagocytosis (pronounced fagositosis), and an individual's resistance to bacterial diseases depends to a great extent upon the activity and efficiency with which his phagocytes deal with the bacteria that enter his tissues. If the medical dictum that a man is as old as his arteries is true, it is equally true—as far as bacterial disease is concerned—that a man is as healthy as his phagocytes. We shall have to return to this extremely important action of phagocytosis in a later chapter.

There is another fluid—the lymph—which pervades our tissues and interposes between the blood and the individual cells of the tissues. It is derived from the blood by a complex process in which selective filtration plays a part. It has its own minute channels, which empty into ducts of increasing size until they merge into one large vessel that returns the lymph to the blood-stream. The lymph is not a tissue, however, because, unlike the blood, it has no specialized cellular composition. Its chief function is to serve as a medium for the exchange of food and waste products between the blood and the tissue-cells, and it is also a vehicle for the removal of bacterial poisons and the poisonous products of cell destruction. It therefore plays an important part in the body's defences. It is, moreover, peculiarly associated with a special tissue of the body, the lymphoid tissue, which deals especially with the removal of poisons from the tissues. The lymph-channels all pass through lymph-glands on their way from the peripheral parts of the body to the great lymph-duct in the chest, and these glands function as poison filters. Most persons have suffered from swollen lymph-glands in the neck as a result of tonsillitis, or of some septic infection of the mouth. The swelling of the glands is the manifestation of their reaction to the bacterial poisons brought to them in the lymph.

The human nervous system, which includes the brain and spinal cord and the nerves that radiate from those organs to every part of the body, possess only a slight faculty of resistance to bacterial attack. It is, however, protected to some extent by enclosure in bony walls and strong membranes, and it is jealously guarded by the general defensive mechanisms of the body. Every fixed cell in the body is linked up with controlling centres in the brain, and our nervous system not only regulates the normal functions of our tissues, but controls also the nature and intensity of their reactions to bacterial stimuli.

Our skeletal system, comprising the bones, cartilages, and joints of our body, also possesses only a relatively slight faculty of resistance to bacterial attack; but it is not often seriously injured, because the structure and composition of bone make it an unsuitable medium for bacterial development, and the joints are protected by the tough ligaments and the muscles that are inserted into their bony surrounds. Only a few pathogenic bacteria, of which *B. tuberculosis* is the most dangerous in this country, appear able to attack our bones and joints with the same ease that they attack the soft tissues of our body.

The various internal organs differ widely in their resistance to bacterial attack, though none possesses a resistance comparable to that of the skin. Their resistance varies against the different pathogenic species, and against the same species at different ages of man, or under different environmental conditions. The same organ may put up a successful defence against one pathogen and succumb rapidly to another; or it may resist successfully in childhood only to be overcome by the same germ later in adult life, and the reverse may occur. The human lung, for example, is resistant to the causal agents of gonorrhœa, typhoid fever, and cholera, but it is susceptible to those of tuberculosis ("consumption"), pneumonia, and plague. Its susceptibility to the causal agent of pneumonia varies widely, however, at different ages of life, being highest in infancy and old age, and under different environmental conditions, being highest among people living in cold, damp climates.

The human body is equipped with several large ducts, or tracts, which afford natural means of entrance for the bacteria that surround man throughout his life. These are the alimentary, respiratory, urinary, genital, and auditory tracts. The alimentary tract, or food canal, traverses the body from the mouth to the anus and is lined with a membrane that is co-terminus

with the skin at each end. It includes the stomach, which is really only a specialized dilatation of the duct, and some thirty odd feet of intestine, or bowel. The space in the lumen (*i.e.*, a transverse section of the clear space within a tube) of the tract is directly continuous with the space in which we live, and therefore any matter, whether food or bacterial, that is lying in the lumen of the tract is outside the body. At first sight this may seem paradoxical; but a little reflection will make it clear that the food we eat, the fluids we drink, and the bacteria we swallow, cannot enter the body-tissues proper until they have been absorbed through, or have penetrated, the walls of the duct. This is an important observation, because most of the foods that we eat and the fluids that we drink are contaminated with bacteria, some of which are pathogens, and in other ways they are continually entering the mouth and are swallowed with the saliva. If every pathogenic bacterium that we swallowed promptly entered the body, we should never be free from bacterial disease. Before these organisms can cause disease, however, they have first to pass through the stomach into the bowel, and then penetrate through the bowel wall into the surrounding body-tissues. The healthy human mouth normally harbours a large population of many different species of bacteria, which lurk in the tiny fissures and folds of the lining membrane, in the crypts of the tonsils, in the spaces between the gums and the teeth, and in any cavity that may form in a decayed tooth. No amount of oral hygiene will eradicate these bacteria, or even appreciably reduce their numbers beyond a minimum that is constant for each individual under natural conditions. Most of these bacteria are saprophytes that have selected the human mouth as their ideal place of residence, and are therefore known, technically, as commensals (*i.e.*, organisms living on or within another, but not as parasites). They feed on the particles of food that lodge in the mouth and they never cause disease under any circumstances. Some of the mouth bacteria are facultative pathogens, however, and from time to time obligate pathogens enter the mouth and are swallowed, or lodge somewhere in the oral cavity. Our saliva, which is continuously being secreted in health, possesses a feeble germicidal power and assists in the defence of the mouth, but its main function in this respect is to act as a mechanical cleanser by flushing out the mouth and sweeping food particles, foreign matter, and bacteria backwards into the gullet, where they are swallowed. The healthy stomach, because of its normal

content of free hydrochloric acid, is an impassable barrier to most of the bacteria that are swallowed. All the mineral acids are very powerful germicides even in weak solutions, and the acid secretion of the stomach, which is formed by special glands in its walls, is not a weak one. Under certain conditions, however, bacteria may evade this secretion, or be protected against its action, and they then pass on with the partially digested food into the bowel. Here they find themselves in the midst of a teeming multitude of bacteria of many different species, because the healthy human bowel normally houses an uncountable host of bacteria. At least one third of the dry weight of the waste fæcal matter that is voided from the human bowel consists of bacteria and microscopic fungi. Many of these bacteria are commensals, but some are facultative pathogens. These do not cause us any trouble, however, as long as they remain within the lumen of the bowel because in this situation they are outside the body and are living as saprophytes upon the inanimate matter that we eat as food.

The respiratory tract is a cul-de-sac that starts at the nostrils and ends in the multitude of tiny air-sacs whose presence is responsible for the spongy texture of our lungs. We are continually drawing bacteria into our nasal passages with the air and dust that we inhale; but, as long as these inhalations pass through the nose, very few of these bacteria ever reach the lungs, or even the wind-pipe, because the healthy human nose is a most efficient filter. Most of the inhaled dust particles and bacteria are trapped in the sticky secretion that normally lubricates the surfaces of the nasal passages, and are then carried backwards into the throat and swallowed, to be destroyed by the acid stomach juice. If the nasal functions are impaired in any way, however, bacteria may be carried down into the lungs with inspired air. Many individuals are unfortunately mouth-breathers and are thus deprived of the filtering mechanism of the nose. The real danger of adenoids is that these abnormal accumulations of lymphoid tissue tend to obstruct the flow of air through the nasal passages and force the individual to become a confirmed mouth-breather. Most of our organs and tissues will only function efficiently if they are kept steadily at work. An organ that is not used gradually atrophies and ultimately becomes useless. This is what happens to the nose of the untreated chronic adenoid individual; it eventually degenerates into a mere appendage that is neither useful nor ornamental and, though the conscientious

performance of simple breathing exercises will partially restore its functions, it will never be as efficient as Nature intended it to be. The mouth-breather is liable to draw bacteria straight into his wind-pipe, and from there it is an easy step to the delicate lung-tissue. Moreover, air drawn in through the nose is warmed to body temperature and is given a certain moisture content before it reaches the lungs. This does not happen to air that is drawn in through the mouth, and the continual impact of dry air, whether cold or hot, upon the delicate lining membranes of the wind-pipe and air-tubes in the lungs reduces their resistance to bacterial attack.

The urinary and genital tracts are both cul-de-sacs also, with a common duct for a portion of their length in the male. The urinary tract starts at the urinary orifice, which is situated at the end of the penis in the male and in the upper third of the vulva in the female. In each sex the duct passes into a specialized dilatation—the bladder—and then divides into two tubes—the ureters—one of which passes upwards to each kidney. The tract is continually flushed as far as the bladder by the urine excreted by the kidneys, and intermittently below the bladder. This flushing helps to remove bacteria and other particles of matter that may have entered the tract, although, under good living and hygienic conditions, bacteria rarely enter the tract from sources outside the body.

The genital tract differs in its course, structure, and functions in the two sexes. In the male it runs from the urinary orifice to the prostate gland, which is situated just in front of the bladder, and then divides into two tubes, one of which terminates in each testicle. The male organ of generation, the penis, therefore contains the portion of the duct that is common to the two tracts. In the female the tract runs backward from the vaginal orifice, situated in the lower half of the vulva, into the womb, where it divides into two tubes that open into the internal abdominal cavity, one on either side of the body, in close proximity to the ovaries. Normally, the entrance to the womb is closed; but during child-birth, and for a short time afterwards, it is open and bacteria may pass through. Child-birth fever, which is responsible for a heavy maternal mortality rate, is caused by the entrance of germs into the womb after its tissues have been temporarily exhausted by the strain of housing and nourishing the developing child and then expelling it through the birth canal (the vagina).

As I have already mentioned, the human bowel normally harbours an enormous bacterial population, and the normal movements of the bowels entail the deposition of many bacteria upon the skin surface around the anus and in the cleft between the buttocks. The most scrupulous personal cleanliness cannot keep this area of the skin free from intestinal bacteria. The anatomical arrangement of the alimentary and genito-urinary tracts in the male safeguards his common duct from contamination by these bacteria; but the external sex organs of the female are so located that the vulva inevitably harbours a bacterial population that is selected from the bowel bacteria that are deposited on the skin, and the vagina, in turn, harbours a population selected from that of the vulva. Under ordinary conditions these bacteria lead a commensal existence on the vulva and in the vagina, but some of them may acquire pathogenic powers if there is any derangement of the normal functions of the female genital tract.

The auditory tract is not of much importance as a portal of entry for bacteria, partly because it is a blind-tube that ends in a cavity enclosed in bone, and partly because it is provided with a germicidal secretion, cerumen, which hardens into the wax of the external ear. Mastoid disease, which is unfortunately all too common among children nowadays, is the result of a bacterial invasion of the blind end of the tract; but the invading bacteria rarely, if ever, enter the tract by way of its external orifice.

To sum up, it is evident that the human body is a complicated structure, built up of different tissues and organs that vary widely in their natural resistance to bacterial diseases and in their liability to bacterial invasion. It also contains numerous cavities and ducts that open to the external world and provide natural ways of ingress for bacteria; but, although the cavities and ducts may harbour a normal population of bacteria, they are each protected to some extent against invasion by obligate pathogens from the outside world either by their anatomical location and structure, or by their natural secretions and functions. The final balance in most cases of contact between a pathogenic bacterium and its human host tends, therefore, to tip over in favour of the host; but many causes, both internal and external, operate to determine the result of each individual struggle between the human body and an invading germ.

CHAPTER IV

INFECTION AND TRANSMISSION

INFECTION is defined as the implantation in the tissues of the body of living pathogenic organisms in such a way as to favour their growth and permit their toxins to injure the tissues. Before they can be implanted in the tissues, however, the bacteria must be brought into the immediate vicinity of, or into actual contact with, the individual, and we must therefore consider the ways in which these contacts are secured, and the methods by which bacteria are distributed among human communities.

The medieval conception of the spontaneous generation of minute forms of life was shattered by Pasteur's brilliant researches on fermentation. We know now that bacteria, in common with all other forms of life, can only take origin from living progenitors of the same type, or, in other words, that bacteria alone can beget bacteria. The causal agents of the bacterial diseases of man must conform to this law, and when they are obligate parasites of man it is evident that the source of infection must be a case of disease, or an individual who is harbouring the particular pathogen responsible for the infection. There are, however, many bacterial infections of man that do not take origin from human sources and it will be necessary, therefore, to consider the sources of infection under two headings—(*a*) human sources, and (*b*) other sources. Some of the bacterial diseases of man are exclusively confined to the human race, and their causal agents are not pathogenic for the lower animals, either under natural or under artificial conditions of infection. It is obvious that a patient suffering from any one of these diseases must have acquired the infection, directly or indirectly, from a human source. Other human bacterial diseases are caused by bacteria that are either responsible primarily for diseases among the lower animals, or are able to cause disease in them as well as in man, and human beings may therefore be infected either directly or indirectly from animal sources. Finally, a few human diseases are caused by bacteria that are primarily saprophytes, and in these cases infection may be acquired from contact with soil, dust, mud, water, or vegetation, containing the responsible bacterium.

Different individuals show wide variations in their reaction

to the same pathogen. This difference is one of degree, not of kind. The individual may show the typical signs and symptoms that are characteristically associated with the active multiplication of the pathogen in the tissues. In such a case he suffers from a clinically recognizable attack of the disease, which may be severe, moderate, or mild in its intensity. He may be so resistant, however, or the virulence of the pathogen may be so low, that he only exhibits symptoms of vague ill-health that are not referable to any of the recognized bacterial diseases. In other words, he is infected, but it is not possible for the doctor to diagnose his infection. If he is strongly resistant, or immune to the particular pathogen, he may carry the bacterium in his tissues for long periods without showing any signs of ill-health. In any widespread outbreak of bacterial disease, which we call an epidemic, all these degrees of infection are present; and in inter-epidemic periods, for every occasional (sporadic) case of disease that is clinically recognizable, there are numerous cases of infection that are unrecognizable. The distribution of a parasite in its host species is always much wider than the recognizable cases of disease. This is in accordance with natural laws. Nature abhors the imperfect, and every case of clinically recognizable bacterial disease in man is an instance of imperfect parasitism, because the host is suffering at the expense of the parasite. The death of the host is a biological disaster for the parasite, because it usually means its extinction also. The perfect parasitic state is attained when the parasite lives with its host without causing any disturbance of the host's health and activities. In every association between man and his bacterial parasites we must expect to find, therefore, all degrees of parasitism from the imperfect to the perfect, and the instances of perfect parasitism will be almost as numerous as those of recognizable disease.

The human carrier of a pathogenic bacterium is an example of perfect parasitism, and he is the most important, because he is the most dangerous, source of infection among his fellows. The patient suffering from a clinically recognizable bacterial disease is generally segregated from his fellows. He feels too ill to move about and maintain his usual daily contacts with his fellows. People are warned against direct contact with him during the stage in which experience has shown that he is infectious, and any discharges from his body that are likely to contain the pathogen are carefully collected and sterilized.

There is one stage in his infection, however, the incubation stage, in which he is as dangerous a distributor of the pathogen as the human carrier. An interval must elapse between the implantation of a pathogenic germ in the body and the onset of symptoms of disease. This interval is occupied by the necessary multiplication of the germ and the elaboration of its poisonous products, because until these have been absorbed in sufficient quantity by the tissues the individual will not feel ill or show any signs of ill-health. The incubation period varies for the different bacterial diseases, but it is constant within narrow limits for the same disease in different individuals. The individual is infectious during the incubation period because his body is ejecting the germs as fast as it can, but he mixes freely with his fellows because he does not feel ill.

Similarly, the human carrier does not feel ill; indeed he may feel in the best of health and spirits and show no signs of ill-health. Neither he nor his fellows therefore have any reason to take precautions; but intermittently he is discharging germs from his body, distributing them among his fellows, and contaminating objects with which he comes into contact. Human carriers of disease germs belong to one of three kinds:

1. *True Carriers*

These are persons who have never suffered from any clinically recognizable attack of the disease for which the germ they harbour is responsible, but who carry it in their bodies for long periods, sometimes for life, without ever showing any signs of its presence.

2. *Convalescent Carriers*

These are persons who have recovered from a clinically recognizable attack of bacterial disease, and who continue to harbour the responsible germ for variable periods of time which seldom exceed a few months, except in the case of typhoid fever and certain related diseases. This type of carrier is less dangerous than the true carrier, because he is known to have had the disease, and is therefore regarded as a potential carrier by the medical services.

3. *Contact Carriers*

These include incubating cases of infection, and persons who are resistant to the particular germ, but who have been in close

contact with a carrier, a case of the disease, or another contact, and who harbour the germ for a few days or weeks without showing any recognizable signs of infection.

These human carriers play an extremely important part in the transmission of bacterial diseases from man to man, and in the rapid and widespread dissemination of a disease among large populations, which we call epidemic spread. In most epidemics of bacterial disease the ultimate source is either a true carrier or a convalescent carrier. Contact carriers are largely responsible for the spread of the agent and often far outnumber the recognized cases of disease. Moreover, but for the true carrier, who represents Nature's ideal association of host and parasite, many pathogenic germs would become extinct with the destruction of the susceptible members of the host species. In connexion with human bacterial diseases, the proper study of mankind is man, as Pope remarked in another context.

The carrier is not always or wholly to blame, however, because the recognized case of disease may be the source of a widespread dispersal of the pathogen as a result of defective segregation, faulty nursing, and ignorance. The germs have no instinctive urge to leave "the sinking ship". They are not constrained by the mating call, or the migratory impulse, to leave the host; but the host's tissues are continually ejecting them by way of the natural ducts, or by the formation of pathological discharges. The natural methods of ejection employed by the human body are either involuntary reflex acts, or voluntary responses on the part of the individual to natural stimuli (*e.g.*, the "calls of nature" in polite parlance). The methods differ according to the different tissues and tracts that are involved, because the alimentary, respiratory, urinary, and genital tracts are natural channels for the ejection, as well as for the ingress, of bacteria. Bacteria are ejected from the alimentary tract by the normal movements of the bowels and, when the infection is established, by the repeated passage at short intervals of fluid motions—the state of altered bowel function known as diarrhœa. (Diarrhœa is the method devised by the body to rid itself of harmful bacteria by washing them out by way of the alimentary tract.) They may also be ejected from the upper part of the tract by the reflex act of vomiting. They are ejected from the respiratory tract by the involuntary reflex act of sneezing, and by the voluntary or involuntary act of coughing. They are ejected from the urinary tract by an

increased flow of urine, associated with an urge to void it at short intervals, and from the genital tract by an increase in the natural secretions, or by the formation of pathological discharges. Similar discharges may also assist in the ejection of bacteria from any of the tracts and tissues of the body.

In urban communities in civilized countries the waste matter discharged from the human bowel is now largely collected and rendered harmless by the modern water-carriage system of sewage disposal. From each dwelling-house and public lavatory the sewage is flushed along a special system of underground pipes to a depot (or sewage farm), where it is scientifically treated to remove all the solid matter and destroy all the pathogenic bacteria it may contain. The fluid portion that remains after this treatment—the effluent—is generally sufficiently harmless to be discharged with safety into a river, or lake, or into the sea. Strict supervision is exercised over the purity of sewage effluents in this country and they are generally innocuous and often surprisingly pure. This method of disposal of human fæces and urine in the mass is probably the most important factor in the gratifying reduction in the incidence of typhoid and paratyphoid fever that has occurred in the British Isles in recent times. Some of our seaside towns discharge their crude, untreated sewage into the sea, where natural agencies gradually break it down and make it harmless. This method is safe only so long as the in-coming tide does not wash the crude sewage in-shore, or up the tidal waters of an estuary, or over areas of edible shell-fish beds. The water-carriage system is impracticable in isolated farms and dwelling-houses in country districts and in remote villages and hamlets. In such places it must be replaced by the individual earth-closet, or, if a water-closet is used, by the cess-pit. These are safe only when they are carefully looked after by persons who are conversant with the dangers attendant upon their use, especially the danger of exposure to the visitation of carrion-flies like the bluebottle and the common house-fly. Whenever any system of sewage collection and destruction breaks down it immediately becomes a serious menace to the community, and the haphazard deposition of human sewage on the soil by hikers, campers, and picnickers is always dangerous. This danger can be illustrated by the consideration of a hypothetical case.

X is a young man, apparently in perfect health, who is an enthusiastic hiker. Years ago, however, he suffered from a

mild and atypical attack of typhoid fever that was not clinically recognizable at the time, since when he has unknowingly been a carrier of *B. typhosus* and, from time to time, has discharged that germ in his motions. On one of his tramps he feels obliged to relieve his bowels, and he deposits the fæcal matter on the soil in the seclusion of a small wood, close to the banks of a little brook, which eventually feeds a reservoir from which a town derives its water supply. Shortly after its deposition, a heavy rainstorm washes the sewage into the brook, and the typhoid germs present in it are carried down into the reservoir. A few days later cases of typhoid fever begin to appear among the inhabitants of the town and, if the Health Services do not act rapidly to substitute a pure water supply for the contaminated one, or to sterilize the contaminated supply, an epidemic of typhoid fever will ravage the town. Fortunately, only a certain number of persons who drink the contaminated water will contract clinical typhoid fever. Many will escape altogether; some will develop a vague illness that can only be suspected to be typhoid fever because of the known cases of the disease in the town, and some will develop the true carrier state. The result will be that a potential focus of typhoid fever is created in the town, and if any of the townspeople who have developed the carrier state move to fresh localities, the danger of the spread of the disease is increased.

Instead of feeding a reservoir, the brook may be the source of supply of a village well situated on its banks. The result will be much the same. Alternatively, there may be no rainstorm, but flies are attracted to the exposed sewage and feed greedily on it, taking numbers of typhoid germs into their own food-canals and contaminating their feet and bodies with many more. After this meal they are attracted to food that is being consumed by a party of picnickers, or to the dairy of a farm where there are uncovered vessels full of milk. When a fly feeds it always regurgitates some of its stomach contents on to the food (*i.e.*, it vomits on to the food), and it is continually voiding waste matter from its bowel on to the food throughout its feeding time. The result is that the food, or the milk, is contaminated with typhoid germs and, in the one case, some of the members of the picnic party contract typhoid fever and, in the other, there is an outbreak of the disease among the consumers of the milk.

These are extreme illustrations of the dangers inherent in the

haphazard deposition of human sewage on the soil of a densely populated country like England; but the danger is there, and only the education of the public can offset it. The haphazard deposition of urine is, in general, much less dangerous than that of fæces; but some human carriers excrete typhoid and other germs in their urine, and the serious epidemic of typhoid fever in Croydon in 1938 was traced to such a carrier.

The natural movement of the bowels is almost invariably associated with some degree of fæcal contamination of the fingers, and in persons who are not scrupulously careful over their toilet some of the intestinal bacteria find a suitable resting-place in the space beneath the finger-nails. Many people, particularly women, regard long finger-nails as an aid to beauty, or a hall-mark of gentility; but they are often repositories for pathogenic bacteria, and even frequent scrubbing with plenty of soap and water will not entirely remove the germs. If a person who is carrying typhoid or other pathogenic germs under his finger-nails works on a farm, or in the dairy of a milk-distributing concern, or in any establishment where food that is eaten uncooked is prepared for distribution, he is a menace to the community. Sooner or later he will contaminate the food or milk that he is handling and some of the consumers will contract a bacterial disease. Boiling, or efficient pasteurization of milk, and proper cooking of other foods, will make them safe for human consumption in most cases, because many of the pathogenic bacteria that enter the human body by way of the food canal are easily destroyed by heat. *Bacillus typhosus*, for example, is easily destroyed by heat; but it is resistant to cold and can withstand freezing for long periods, which explains why ice-cream is sometimes the vehicle for outbreaks of typhoid fever. It can also remain alive in fresh water for as long as three weeks in these islands, and it remains alive in human sewage exposed to the air for several days, if it is shielded from direct sunlight. Strong sunlight kills the germ rapidly. If, therefore, hikers, campers, cyclists, and holiday-makers are obliged by nature to defaecate in the open, they should at least choose a sunny spot for the operation. Preferably, they should dig a little pit and see that the fæcal material is properly buried before they leave.

When any irritant matter lodges in the nasal passages the reflex act of sneezing is brought into play. If it lodges in the wind-pipe, or in the air-tubes of the lungs, the reflex expulsive act of coughing comes into operation. The expulsive force in both these actions

is considerable, and the offending particles may be expelled to a distance of several feet. Bacteria are such minute bodies that a moderate force will project them to a distance of several feet and, though they are heavier than air and must therefore sink to the ground in still air, they are so light that quite small air-currents are sufficient to keep them suspended for a long time. We can obtain some idea of the part played by sneezing, coughing, and spitting in the spread of bacterial diseases by considering some more hypothetical illustrations.

The scene of our first illustration is almost any municipal or public service omnibus or tram-car on any cold, damp, winter evening. The vehicle is crowded with people anxious to get home from their work to their evening meal and the warmth and comfort of the fireside. One of the passengers, Y, has a bad nasal cold, and is either an inconsiderate or an ignorant individual (probably both), because from time to time he sneezes violently without making any effort to catch the ejected matter in a handkerchief or in his hand. Every time he sneezes he expels large numbers of tiny droplets of nasal secretion, each of which is loaded with bacteria, and distributes them liberally and impartially over all the other occupants of the bus or tram. His fellow-travellers are obliged to inhale some of these germs into their respiratory passages, with the result that some of them fall sick in a day or two with bad colds, and possibly one or two, more delicate than the rest, or unable to breathe through their noses, go down with an attack of pneumonia.

We can vary the scene by choosing a railway carriage for our second illustration, and visualize a crowded compartment on a suburban line. One of the occupants is Z, a surly fellow with strong opinions about the rights of the individual and an active tuberculous infection of his lungs. From time to time he coughs up from his lungs a quantity of material containing large numbers of tubercle bacilli and, in defiance of the wise bye-law prohibiting spitting, he deposits this material upon the floor of the carriage. It dries rapidly in the heated, closed compartment, and is ground into powder by his feet and those of his fellow-travellers. Air-currents lift the dried particles with their cargoes of *B. tuberculosis* into the air, where they may be inhaled by some of the other occupants of the carriage, with the risk of contracting a tuberculous infection of the lungs, a disease that is better known to the general public as " consumption ".

For our third illustration we can imagine a girl with a chronic

infection of the throat, or lungs, who serves in a sweet shop, or in a shop where any food is retailed that will be eaten without further cooking. During the day she repeatedly coughs over the food or sweets, each time spraying them with a multitude of germs. She would certainly be horrified to learn that a child had died as a result of her ignorance or carelessness, or that an older person had spent days or weeks on a sick-bed; but there is no room for ignorance, indifference, or carelessness in the unceasing struggle between man and germ. Even during the act of quiet talking, droplets of saliva loaded with germs are continuously being sprayed out from the mouth up to a distance of about eighteen inches, and shouting and crying greatly increase both the number and the range of these droplets. The expulsion of germ-laden droplets of fluid matter from the human respiratory tract is responsible for the type of infection known as " droplet " infection, and it is one of the most important methods of spread of certain microbial diseases of man, especially of those diseases that are particularly prevalent in childhood, such as measles, whooping cough, mumps, german measles, scarlet fever, and chicken pox. Among adults it is the chief method of spread of the common cold, tonsillitis, influenza, pneumonia, and, to a lesser extent, consumption.

The expulsion of bacteria from the genital tract is not of so much general importance; but it is the decisive factor in the spread of the venereal diseases, the transmission of which depends almost entirely upon sexual intercourse.

It is evident from what has been said that pathogenic bacteria can be transferred from one individual to another in one of two ways—namely, (*a*) by direct personal contact, which includes droplet infection, or (*b*) indirectly, through contact with some third party, which may be either another human being, an animal (in the widest sense of a living member of the animal world), or some inanimate object that is contaminated with germs.

The common means of direct contact infection are (*a*) " droplet ", and (*b*) actual contact of body surfaces. Apart from the transmission of the venereal diseases, kissing is the chief act of bodily contact between two individuals responsible for the transmission of bacterial diseases. It is extremely doubtful, however, whether this fundamentally insanitary habit will ever be abolished while human nature is what it is. Most readers will probably agree that a kiss is worth a germ or two, and unhappy is the man or woman who has never been kissed, at least in the estimation

of those who have acquired proficiency in the art. Nevertheless, every kiss means either the deposition of germs upon the skin surface of the recipient, or an interchange of germs between the participants. As long as neither operator harbours any obligate pathogens in his or her mouth no harm is done; but if the one harbours a pathogen, the other runs the risk of contracting the disease for which that pathogen is responsible. Speaking as a man and not as a bacteriologist, I am prepared to agree with the majority of my readers that the risk is, in most cases, worth while. Speaking as a bacteriologist, I must warn the reader that kissing, especially among school-children, is a fertile method of distributing infections of the human respiratory tract.

While we are on the subject of kissing, it may be worth while to emphasize that no dentifrice, however cleverly it is advertised, and no amount of brushing of the teeth, washing out the mouth, and gargling, will exert any marked reduction upon the germ population of the mouth. Regular brushing of the teeth with a palatable, bland dentifrice keeps the teeth clean and white, which definitely enhances one's personal appearance, and protects them to some extent from decay by mechanically removing the particles of food that otherwise remain lodged in the crevices between the teeth. When these food particles are decomposed by the mouth bacteria, local accumulations of acid are formed, and it is these spots of acid acting upon the enamel covering of the teeth that start the decay. It is impossible to sterilize the human mouth by any method that will not cause agonizing suffering and probably result in the death of the individual.

Turning now to the problem of indirect contact infection, there are innumerable channels by which bacteria can be conveyed indirectly from a human carrier, or a case of disease, to other persons. Practically any object of household, workshop, or office use can serve as a passive means of transference, although the risk of such transference is confined to those pathogenic germs that are able to survive outside the human body for a period of days. Delicate pathogens like the causal bacillus of whooping-cough are rarely transferred in this manner; but relatively hardy ones like *B. diphtheriæ* are commonly distributed in this fashion. The spread of diptheria among school-children often results from the deposition of the bacillus in droplets of saliva from the mouth of an incubating case of the disease, or from a carrier, on desks, books, pens, pencils, toys, and food utensils. These are handled by other children, who thereby pick up the diphtheria

germ on their fingers. It is surprising how often in the course of an average day our fingers are brought into contact with our lips, so that once bacteria are on our fingers it is almost a certainty that they will be conveyed to our mouth. Little children are also prone to suck their fingers, and diphtheria is commonest among children of from five to ten years of age.

Inanimate objects that serve as mechanical vectors (from the Latin verb *vehere*, to carry) of bacteria are technically called fomites (pronounced foemit-tease). They may be contaminated by droplets from the respiratory tract, by fæces (pronounced fee-seas) and urine, by abnormal discharges from diseased tissues, or by direct contact with the fingers, lips, or other body surface of an individual who is harbouring a pathogenic germ. The precise mode of contamination will depend on the route by which the germ is being expelled from the host's body. Uncooked foods, milk, and water can all function as fomites, and illustrations have already been given of the way in which these substances can act as mechanical distributors of the causal agent of typhoid fever.

Some of the bacteria that are pathogenic for man are also pathogenic for certain of the lower animals, and there are certain primary microbial diseases of the lower animals that are transmissible to man. The first of these groups is of relatively minor importance, but the second includes some of the deadliest microbial diseases to which man is subject. For example, plague is primarily a disease of the rat; anthrax of cattle; glanders of the horse; hydrophobia (or rabies) of the dog; Malta fever of the goat; tularæmia of the rabbit; infective (or spirochætal) jaundice of the rat; bovine tuberculosis of cattle, and undulant fever of cattle. Man is frequently brought into close contact with his domestic animals, and the rat pervades all human communities.

Finally, certain insects are able to act as mechanical vectors of human pathogens, and others are vitally important intermediate hosts of various microscopic forms of life that parasitize man. In this country the common house-fly, and the carrion flies of the bluebottle family, are our most dangerous insects in the mechanical dissemination of human bacterial diseases. Fortunately they are only prevalent during the summer months, but during that period they are responsible for a large volume of human disease. No educated person ought to tolerate these flies in the dwelling-house, or in a shop or establishment where food is exposed for sale, or is prepared for human consumption.

The house-fly could be practically exterminated by a resolute national campaign, and every dead fly is another potential menace to man removed. The gnat and the midge, voracious blood-suckers that sometimes spoil the charm of a summer evening, are also sometimes responsible, indirectly, for serious infections. Their bites frequently set up an intolerable itching and the victims are obliged to scratch the itching spot. If pathogenic bacteria are present under the finger-nails, they may be rubbed into the puncture wound in the skin made by the insect, and the result is a septic infection that sometimes kills the individual.

There are some very dangerous microbial parasites of man that pass one part of their life-cycle in the human body and another essential part in the body of an insect. Malaria, one of the greatest scourges of mankind, which even now renders some of the most fertile regions of the earth uninhabitable by man, is one of these diseases. The causal agent is a microscopic animal, which passes an asexual cycle in the red cells of the human blood and a sexual cycle in the body of a certain species of mosquito. Human malaria is a self-limiting disease, which can only be transmitted from man to man under natural conditions by the bite of the mosquito. The parasite has only a limited capacity for asexual multiplication in the human body, and must therefore spontaneously die out in time unless its reproductive activity can be renewed by a sexual cycle in the mosquito. The Panama Canal, one of the greatest engineering triumphs of man, could not be completed until Colonel Gorgas and his colleagues of the American Army Medical Service had abolished malaria in the Canal Zone by destroying the breeding-places of the mosquitoes that were decimating the workers by their transmission of malaria. Typhus fever, another deadly human disease, which used to be so prevalent in our gaols that it was known as "jail fever", is only transmissible to man through the bite of the body louse. The causal agent passes through a vital cycle of development in the body of that insect, and the eradication of the disease from these islands in recent times is entirely due to the near extinction of this insect, and to the abolition of the appalling conditions of overcrowding in our cities that forced lousy individuals into close personal contact with their fellows. Burns' "Highland Mary" was one of the last persons to die from typhus fever in Great Britain. Most of the agents of disease that require an intermediate insect host for their propagation and transmission to man are protozoa—microscopic forms of life that are placed in

the Animal Kingdom—but it is probable that some of the Ultramicroscopic Viruses may require to undergo some degree of development in the bodies of insects before they are infective for man. No pathogenic bacteria are known that possess, or require, a sexual cycle in an insect host; but, as I have already emphasized, many bacterial diseases of man can be disseminated by the mechanical agency of flies, mosquitoes, lice, fleas, and bedbugs.

CHAPTER V

DEFENCE, RESISTANCE, AND IMMUNITY

We have dealt with the methods by which pathogenic germs may be brought into contact with the individual and implanted in the body, and with the properties that enable them to break down the local resistance of the tissues and cause infection. We must now consider the mechanisms by which the healthy human body normally defends itself against bacterial attack.

It is not possible to give a definition either of health or of normality where man is concerned; but a state of good health is manifested by mental and bodily activity, by efficient discharge of the multiple functions of the tissues, and by freedom from the symptoms and signs of microbial or other disease. This state is probably never constant; it fluctuates from week to week, even possibly from day to day, and it is influenced by many external factors. The food we eat, the work we do, the exercise we take, our mental and emotional reactions to the problems of everyday life, economic conditions, and environmental factors, all play a part in determining the natural state of health of any particular individual at any particular time. It can be stated, however, that if the human body is given a sufficiency of good, plain food in a reasonably varied diet, fresh air, regular exercise within the physical capacity of the individual, and regular relaxation of mind and body—which includes rest and entertainment—it will keep itself in a state of good health and will put up a successful resistance to most bacterial infections.

Civilization is not entirely a blessing, because it introduces many additional factors and complications that are not experienced by man in a primitive state. Over-indulgence, fatigue, and worry are the three concomitants of civilization that probably

do most to undermine the natural defences of the body by destroying its inherent capacity for efficient function.

Over-indulgence in food is a grave fault that is all too common among civilized peoples. The fact that the individual is not required to hunt, swim, climb, dig, or search for his food deprives him of valuable exercise. Many men and women in our urban communities live sedentary lives. The exercise they take, if they take any at all, is spasmodic and often too violent at the time. The human body at rest requires surprisingly little food intake to keep it functioning effectively. The excretion of waste matter from the bowel and the kidneys cannot be efficiently performed if the body is cluttered up with unnecessary food and insufficient exercise is taken, and the accumulation of these waste products rapidly lowers the resistance of the body to bacterial attack. Chronic constipation is one of the most powerful allies of the pathogenic germ, and artificial purgation with any of the multiple patent remedies that are so widely advertised is not a satisfactory substitute for the regular, natural movement of the bowels. The bowels can only act regularly and efficiently if they are regularly supplied with suitable material on which to act. Fruit and vegetables assist the proper functioning of the bowels; a surfeit of starchy foods tends to inhibit their action.

The kidneys can only perform their function of eliminating waste matter efficiently if they are provided with the necessary quantity of water. This quantity varies with the individual, but many people do not drink enough water. The substitution for water of an excessive amount of alcoholic beverages does not help matters, because alcohol in excess interferes seriously with many of the bodily functions. Excessive tea-drinking also does not supply the proper water content that the kidneys require. Nature provided man with fresh water as his universal and indispensable drink, and there are no efficient substitutes for it. The human body can survive for some weeks without food, if it is kept at rest; it cannot survive for more than a few days without water.

Fatigue, whether of body or of mind, slows down the vital functions and thereby lowers the general resistance of the individual. The tired man cannot digest his food properly. The messages that are being continually flashed to his brain from all over his body meet with lethargic (sleepy) responses—the central telephone exchange is too drowsy to function properly for the time being. The result is a partial loss of that vital co-

ordination of the various functions of the different tissues that is essential for a state of good health. Deprived of proper control, the different organs and tissues begin to compete against each other instead of working together as a team, and the result is that any inherent weakness in the make-up of the individual is aggravated.

Worry is a state of mind that is difficult to define, because it differs in the individual; but its basic cause is fear, and fear is an emotion that has far-reaching effects upon the activities of the human body, accentuating some and depressing others. There are certain glands in the body, grouped together for convenience under the name of the Ductless Glands, that manufacture powerful and vital secretions. The thyroid, parathyroid, pituitary, suprarenal, and internal sex-glands secrete substances that not only regulate the growth and bodily activities of the individual, but also influence in some degree his behaviour and his reactions to his environment. The activities of these glands are, in turn, affected by emotional states, and, while as yet we have no precise knowledge about the effect upon them of the emotion of fear, there is no doubt that they are affected and that the effect is probably detrimental.

It is evident therefore that many factors operate to determine the state of health of the individual. Good health is synonymous with a high degree of resistance to bacterial attack. Any influence that lowers the general bodily health of the individual reduces his resistance to that attack. We have no means of measuring the precise state of health of an individual at any particular time, though we may deduce from medical observation and examination that he is in a general way in good or bad health, and we therefore cannot measure his resistance to the attack of a particular pathogen, even if we know accurately the virulence and dosage of the germ at the time of attack, and the path by which it entered the body. If the individual shows no symptoms or signs of ill-health consequent upon the attack, we have no evidence that he has been attacked, and the severity of the degree of ill-health does not necessarily run parallel with the virulence and dosage of the germ.

When a pathogenic bacterium enters one of the external cavities, or ducts, of the healthy human body it does not find itself on virgin soil, but on a soil that is densely colonized by a variety of germs that have adapted themselves to their particular environment. Some of these colonists may help the pathogen to

establish itself as a result of their mutual association, others may retard its development or even prevent it from gaining a foothold. Whatever may be the outcome of the association, every pathogenic germ that enters the nasal passages, the mouth, the bowels, and the vagina has first to establish itself in association with, or in competition against, the bacteria that are already in possession of the soil, and the influence of the normal flora is probably in most cases favourable to the host.

When a pathogenic germ has established itself in the body and has begun to multiply and manufacture its poisons, the body's first line of defence, phagocytosis, is brought into play. Warning signals are flashed along the nerves to the brain, and are relayed from that organ to the special tissues of the body whose function it is to make the white leucocytes of the blood. These wandering phagocytes are formed by the continual growth and repeated division of specialized fixed cells. The manufacture of wandering phagocytes is continuously in progress in the absence of any bacterial invasion of the body, because new cells are constantly required to replace the veterans that have become worn out by their ceaseless patrol of the body. Under the stimulus of bacterial attack, and the resulting urgent messages from the brain, the phagocytic factories work overtime and speed up production, so that greatly increased numbers of these cells are rushed into the blood-stream. They are attracted to the spot where the germs have established themselves by a mysterious force that we speak of technically as chemotaxis (*i.e.*, chemical attraction), though we really know very little about it, and they hurry to the scene of action from all parts of the body. When they come into contact with the bacteria some of them are killed by the bacterial poisons, but others wrap themselves round the germs and destroy them, and others kill or weaken the germs by liberating germicidal substances against them. Meanwhile, the cells of the tissue in which the germs have ensconced themselves have not been idle. Those that are not rapidly destroyed by the germs undergo chemical and/or structural changes that enable them to put up a better resistance to the attack. If the germ is only present in small numbers and is easily destroyed, the individual may never be aware of the combat that has been fought within his body. If, however, the germs are numerous and powerful, the struggle soon results in a local accumulation of dead bacteria, decomposed tissue, and dead leucocytes, the whole composing a dead tissue that is technically known as pus (pronounced with a short u, as

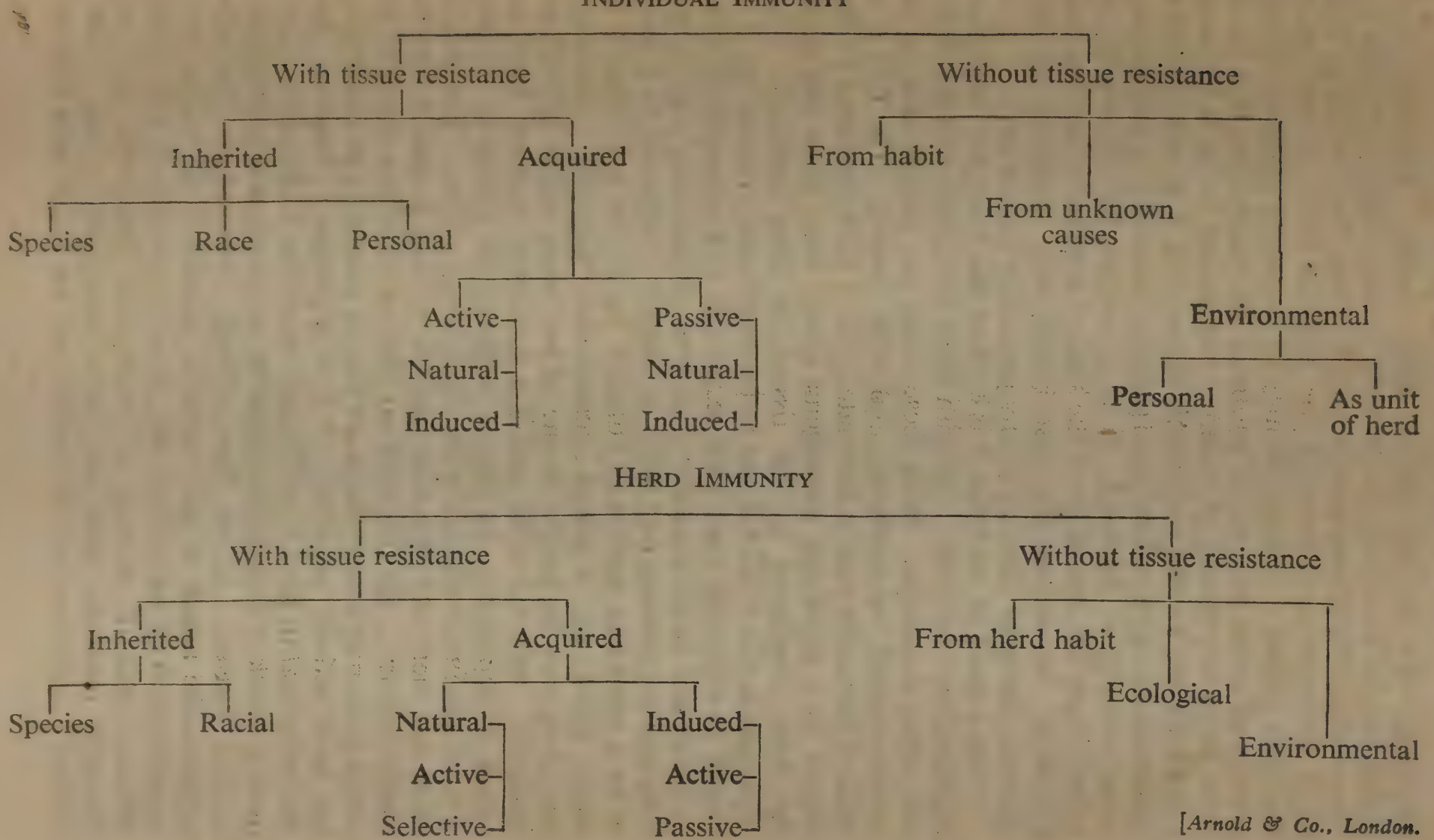
in pun, not as puss) and popularly as matter. The thick, yellow fluid that oozes from a boil in the skin when it is "ripe" is pus, and the same dead tissue fills the cavities of abscesses wherever they may form in the body. When the abscess is near the surface of the body, the body endeavours to rid itself of the germs by discharging them to the outside world in the pus; but when it is situated deep in the body, the surgeon is often required to assist Nature by cutting open the abscess to allow the pus to drain away. Once the germs have been killed and washed out, the recuperative powers of the body rapidly repair the damage that has been done, although the repairs are never quite so efficient as the original tissue. Wherever the combat has occurred the process of repair is the same, independent of the nature and function of the tissue destroyed. The body is more concerned to maintain continuity of structure than of function, so that if the damage has been extensive the function of the tissue may be seriously impaired, even though the battle has been won. If the germs are very virulent and the local tissue defences are weak, a progressive invasion occurs, accompanied by an increasing degree of poisoning as the bacterial toxins are progressively liberated and absorbed by the tissues. Phagocytosis still continues, but the battle now has to be fought on a wider front. It ceases to be a local skirmish and becomes a war of movement, necessitating a general mobilization of the defensive mechanisms of the body. Some of the fixed tissue-cells are active phagocytes, and these engulf any germs that come into contact with them. The circulation of the blood in the affected area is accelerated and increased, the change being shown by a rise in the rapidity of the pulse rate. The general body temperature is raised, because heat accelerates most chemical reactions including those that take place in the human body, and the individual manifests some degree of fever. The cells of the human body have a wonderful capacity for making specific antidotes to bacterial poisons, specific antibodies to react with bacterial antigens, and germicidal substances that act upon the germs themselves. The manufacture of these various substances is speeded up by the increased rate of the blood-flow—which acts somewhat like a forced draught to a furnace by increasing the supply of oxygen—and the raised temperature, and they are poured out into the blood-stream in increasing quantities and hurried to the battle-ground. In many cases this mobilization of the body's defences checks the spread of the bacterial invasion, and when the germs have again

been localized, albeit on a wider front, they are gradually destroyed by the phagocytes. Even when the germs manage to get into the blood-stream and become widely dispersed over the body, they may still be localized in multiple combats with the phagocytes, although septicæmia—which is the medical term for this generalized invasion of the blood—is always a very grave condition. In most cases the body eventually emerges victorious from the fight, though sometimes only after weeks or months of unremitting and exhausting struggle. Much depends, of course, on the physique and general health and vitality of the individual prior to the attack, and on the virulence and dose of the germ; but only a very virulent germ in large numbers can overwhelm the defences of a strong and healthy individual. The battle is never lost as long as life still lingers, and people make remarkable recoveries after medical science has pronounced their cases to be hopeless. On the other hand, it is dangerous to be too optimistic and treat the infection as trivial, because bacteria can overwhelm the body's defences with almost inconceivable rapidity, especially when they are assisted by ignorance, incompetence, and foolhardiness. A seemingly insignificant cut or scratch may result in a fatal septicæmia, and a small boil in the skin that has been squeezed, or scratched with dirty finger-nails, may lead to the rapid death of the individual. Pathogenic bacteria must never be treated with contempt; but there is no need to go about in a permanent state of fear over the germ bogey, or to waste money and ruin one's inside by pouring into it the innumerable patent medicines that are so popular and so pernicious. Cleanliness and good living are sufficient armour in most cases and, when these fail, prompt medical attention will usually give the individual the best chance of survival.

Infection does not necessarily result from the mere implantation of a pathogenic germ in the human body. The soil may be naturally unsuitable for its development, or it may have been made unsuitable by natural or by artificial means. In other words, a particular individual may be naturally immune to a particular pathogen, or he may acquire an immunity to it. In every outbreak of bacterial disease, some persons who are exposed to the risk of infection escape the disease because they are immune. Immunity is, however, always a relative, never an absolute, state of freedom from the consequences of bacterial attack. Unfortunately, the term is often incorrectly used, even by medical men, to imply an absolute freedom from bacterial

attack. No such state can possibly exist on this planet where man is concerned, because bacteria are ubiquitous, and there are no practicable measures that we can take to protect an individual, or a community, absolutely from their attack. The mere fact that man normally harbours in his body many bacteria that are potential pathogens makes this usage of the term erroneous and misleading. Correctly used, immunity means that an individual, a herd, race, or species, is free from the injurious consequences that would otherwise result from infection with a pathogen. The pathogen may enter the body, but it is unable to develop its invasive and poisonous powers. The individual is immune, not because he is safeguarded against the attack, but because his body is able to check it before it can develop. As immunity is always a relative state, it is not surprising that the mechanisms responsible for its origin and maintenance are not always the same, or that different types of immunity exist. An individual may be immune to a particular bacterial disease only so long as he lives in a particular place, or among a particular herd, or so long as he engages in a particular occupation. His immunity may be lost immediately any one of these conditions is changed. A community may be immune, although a large number of its members are susceptible, as long as it inhabits a certain locality, leads a particular kind of life, or is subject to particular climatic conditions. Conversely, a community may be susceptible although many of its members are immune. Herd immunity often differs in kind from individual immunity, and it does not necessarily depend upon the summation of the immunity of its members. Two distinct types of immunity are easily recognized, namely, (*a*) natural, and (*b*) acquired. Each of these types may be peculiar to an individual or to a herd, so that each must be considered under the sub-headings of (*a*) individual, and (*b*) herd immunity. In order to facilitate the presentation of the subject, I have copied the table on p. 55 from *The Principles of Bacteriology and Immunity*, 1929, by W. W. C. Topley and G. S. Wilson. A careful study of this table by the reader will, I hope, enable him to follow more easily the explanation of the different types of immunity, and to comprehend the part they play in the ceaseless struggle between man and germ.

Individual immunity, as its name implies, is a state that is peculiar to an individual and is not common to the herd, although a similar state may be possessed by several individuals in a herd. The individual is not immune against all the known pathogenic



[*Arnold & Co., London.*

bacteria; only against one or more species. Immunity is a highly specific state, and the fact that an individual is immune to the attack of the causal agent of scarlet fever does not mean that he is immune to pneumonia, or typhoid fever, or any other bacterial disease. Indeed, he may be extremely sensitive to the attacks of some pathogenic germs at the same time that he is immune to the attacks of others. No human being is immune against all the known pathogenic germs, and it is very doubtful whether such an immunity could possibly be gained by any means, either natural or artificial. It is important for the reader to grasp clearly the specificity of the state of immunity, because this specificity determines the distribution and incidence of the different bacterial diseases in any particular human herd.

From a study of the table, it is evident that there are two kinds of individual immunity: (*a*) with tissue resistance, and (*b*) without tissue resistance. Both these kinds are usually relative to environmental, occupational, and other factors. The first is a state of immunity that is associated with a high resistance of the tissues to a particular pathogenic germ, even when the germ has been implanted in the tissues in large numbers. The pathogen is able to gain access to the individual's tissues, but it is unable to overcome their local resistance, and consequently fails to infect and cause disease. This type of immunity may be an inherited possession, and often is when it is common to a race, or to a particular species of animal; but in the individual it is more often an acquired possession. Acquired individual immunity may be gained in one of two ways, either actively or passively. When a child makes a successful recovery from an attack of diphtheria, its tissues acquires the power to protect it from any future attacks by the diphtheria bacillus. The tissues work out their own salvation and the process is one of intense bodily activity. We therefore say that the child has acquired an active immunity to diphtheria, or that its immunity to diphtheria has been actively acquired. It is not necessary, however, for the individual to have to suffer and overcome a clinically recognizable attack of diphtheria in order to acquire an active immunity to that disease. As we have already observed, a clinically recognizable attack of any bacterial disease is an extravagant manifestation of parasitism, and, in any outbreak of a bacterial disease, cases of atypical infection, and infections that are clinically unrecognizable, are more numerous. These "subclinical" infections act as stimuli, and we know now that in-

fections that are so slight and transient as to escape detection are able to immunize the individual. Let us consider a hypothetical case as an illustration. John Bull is a sturdy youngster, five years of age, who has just started to attend school. A week or two after his start one of his classmates is taken ill with diptheria. John's mother notices that for a day or two he is a bit off-colour and has lost his appetite, but there is nothing to suggest that he is ill, and very soon he has regained his normal appetite and activity. Six months later, another of his classmates contracts diphtheria, and shortly after several are ill with the disease, but John does not turn a hair. Two years later, his little sister contracts a severe attack of the disease and is desperately ill, but although John has been in close contact with her he remains perfectly well. What is the explanation of his freedom? John was naturally strong and in good health when he first received a small dose of diphtheria bacilli. Possibly the bacilli were not especially virulent when they were implanted on his tonsils, after he had sucked the pencil that his classmate lent him just before he fell ill with diphtheria. At any rate, John's tissues were able to smother the bacilli before they could harm him and, as a result of this successful defence, they gained the experience to deal effectively with the diphtheria bacillus. In other words, they were now mobilized againt the germ, on the look out for its appearance, and John's immunity had begun. Six months later, John received quite a large dose of the bacilli during the outbreak that affected several of his classmates; but his tissues had been forewarned, they were already prepared to meet the invasion, and John's immunity was further strengthened. When his sister contracted the disease, he received several doses of bacilli from her, each of which would have sufficed to make him very ill, if his tissues had not had their previous training. By this time their Maginot line was, however, impregnable to all attacks by the diptheria bacillus, and John was made finally immune by their successful resistance. During the rest of his lifetime, John will often encounter the diphtheria bacillus, at school, at play, at work, and in the home; but he will never suffer from diphtheria. There are many adults in this country to-day who have had the same experience as John, and who have to thank the unseen resistance of their tissues, their good heredity, and a clean and healthy upbringing, for protecting them against diphtheria. What is true for diphtheria is equally true for scarlet fever, whooping-cough, cerebrospinal fever, infantile paralysis,

and other bacterial diseases of childhood. It is true in some cases even for measles, mumps, and chicken-pox, the three most infectious diseases of childhood, because there are people who pass through life without suffering from these diseases; but there is no one, in a densely populated country like England, who passes through life without coming into contact with the causal agents of those diseases. In most cases, however, immunity to measles, mumps, and chicken-pox is gained by a successful resistance to a clinically recognizable attack of the disease. While some individuals acquire an active immunity as a summation of the successful resistance of their tissues to sub-clinical infections, others never acquire a complete immunity even after recovery from a disease. Second attacks of measles, mumps, chicken-pox, diphtheria, scarlet fever, typhoid fever, and certain other bacterial diseases, are rare; but they do occur and, occasionally, people are encountered who have had multiple attacks. Recovery from one attack generally confers some degree of protection upon the individual, however, so that subsequent attacks are milder and more easily overcome. In all these diseases the degree of immunity acquired depends upon the soil, *i.e.*, upon the capacity of the tissues to acquire the necessary experience and means to deal effectively with subsequent attacks. There are other bacterial diseases against which no individual ever acquires a complete immunity, even after successful resistance to one or more attacks. Epidemic influenza is one of these diseases, and in any epidemic of this disease it is usual for some persons to suffer from two or more attacks. Epidemic influenza is so highly infectious that most members in any community that is attacked contract the disease; but the death rate is generally low (except during a world-wide epidemic, like the one that ravaged the world in 1918–19) and most people recover. When the next epidemic comes along, however, and influenzal epidemics recur every few years, they fall ill again, because any degree of immunity they had acquired from their successful resistance to the previous attack was of a feeble and transient nature. In this case it is not the soil that is primarily at fault, but the germ itself. The human body tissues can only manufacture immunizing antibodies, and can only train themselves to an effective resistance, if they receive a sufficiently powerful stimulus. There are some pathogenic germs that are biologically incapable of supplying this necessary stimulus, and the causal agent of epidemic influenza is one of them. The causal agent of the common cold

is another. The reader should bear this important point in mind, because we shall refer to it when we come to consider the methods that medical science has discovered for the production of an active immunity to bacterial diseases by artificial means. We must recognize that there are some individuals who cannot acquire immunity, or be immunized, and some germs that cannot stimulate the tissues of the human body to produce a lasting immunity.

The second type of acquired immunity is obtained by the transference of an immune state from one individual to another. The body-tissues of the recipient take no part in the production of the immune state, they do not work actively to form the necessary immunizing substances, and so we say that the immunity that has been conferred upon the individual has been passively acquired. We have already seen how John Bull's tissues actively protected him from diphtheria. Now we will see how his baby brother acquired his immunity to diphtheria. The reader will remember that John's little sister fell ill with the disease. Her mother, who was pregnant at the time, could not bear to part from her little daughter and so, instead of sending her to the Fever Hospital as the family doctor advised, she nursed her devotedly at home. Mrs. Bull had, however, passed her childhood on a farm in a remote country district, and had never encountered a big dose of a virulent diphtheria bacillus until she nursed her daughter. The degree of immunity that she had acquired from her rare contacts with small doses of feeble bacilli was too slight to protect her and, just as her daughter had turned the corner on the road to recovery, she fell ill with the disease. But she was naturally a strong woman, and had lived a clean and active life, so her tissues were able to deal with the infection successfully. All through the struggle, while her tissues were making the specific antitoxin to neutralize the diphtheria toxin, John's baby brother was developing in her womb, nurtured by the blood that circulated in his mother's body. This blood was full of the specific diphtheria antitoxin by the time that Mrs. Bull had recovered from her attack of diphtheria, because her tissues had made far more than was necessary to destroy the diphtheria toxin, and the surplus had been poured into her blood-stream. Consequently, when Baby Jim entered the world in due course, he started with a good supply of the specific diphtheria antitoxin that his mother's tissues had made. His tissues had taken no part in this process; indeed, they had never encountered the

diphtheria bacillus, because that germ never enters the human blood-stream, and therefore could not possibly have reached him in the security of his mother's womb, and the diphtheria toxin circulating in his mother's blood was neutralized before it reached his tissues. Just before he was a year old, Baby Jim did receive a large dose of diphtheria bacilli from a carrier who insisted on hugging and kissing him—much to his mother's disgust—but he was so well supplied with antitoxin that his tissues, metaphorically, just laughed at the germ, and the only result of its attack was that he acquired an active immunity that gave him protection against diphtheria for the rest of his life.

Passive immunity can only be naturally acquired against a limited number of bacterial diseases. It is probable that some degree of resistance to many others can be transferred from the mother to the child in her womb by way of her blood-stream, and also to the newly-born infant through the medium of the maternal milk; but these degrees of protection are too slight to protect the child from contracting the diseases, although they render invaluable service in assuring a recovery. Where Nature fails, medical science has stepped in in the case of certain bacterial diseases, and has evolved ways of conferring a passive immunity artificially upon the individual. We shall discuss the methods of inducing both active and passive immunity when we deal with Artificial Immunity in the next chapter.

Our knowledge about the mechanisms responsible for a state of immunity without tissue resistance is scanty and incomplete. In many instances this type of immunity would appear to be a relative inability on the part of a particular pathogenic germ to make contact with a particular individual, rather than a true resistance of the individual to bacterial attack. Freedom from bacterial disease may, for example, be conferred upon an individual by his environment, his occupation, or his mode of living, and may disappear as soon as he changes any of those conditions. Many persons in this country enjoy a relative immunity to anthrax simply because they are not brought into contact with cattle or their products. Malta fever is practically confined to goatherds and people who drink goat's milk, or eat cheese made from it. Many bacterial diseases are closely associated with certain occupations, and persons who do not follow those occupations are protected against contact with the germs. If contact is made, they contract infection with the same ease as individuals who are engaged in the occupations affected.

We are relatively immune to malaria in this country simply on account of our environment; many Britons who live in the tropical regions of our empire contract the disease. The best example of this kind of immunity is supplied by the rabbit. In its natural state the wild rabbit very rarely, if ever, suffers from tuberculosis; yet it is extremely sensitive to experimental infection with *B. tuberculosis* in the laboratory. Evidently there are some factors in the rabbit's method of living under natural conditions that give it a relative immunity to tuberculosis. An individual who has no tissue resistance to a particular parasite may be immune from its attack because he is a member of a herd that enjoys a relative immunity by reason of its location or habits. The individual immunity may be lost immediately such a person moves from the one herd into another with different habits or surroundings.

Immunity in the individual implies an absolute or relative freedom from a clinically recognizable attack of a particular bacterial disease when the individual is exposed to the risk of infection. This immunity may, or may not, be associated with a tissue resistance to the particular pathogen. The term can only be applied when there is a risk of infection; but it is valid even though the risk is extremely slight. If there is absolutely no risk, we cannot say that the individual is immune, because his bodily defences can never have been tested.

A community, or herd, of human beings may be said to be immune to a particular bacterial disease if the disease fails to spread among the herd after its introduction into it. A boy at a boarding school comes back from his holidays in the incubation stage of scarlet fever, and is ill with a clinically recognizable attack of the disease after the term has begun. If the disease is limited to him and a few of his schoolfellows, the bulk of the boys showing no evidence of infection, that particular herd is immune to scarlet fever. This herd immunity is not necessarily dependent upon a high average of tissue resistance among the members of the herd. Indeed, a herd may be immune and yet contain many members who are susceptible to the particular disease. Conversely, a bacterial disease may spread widely among a herd, many of whose members are resistant to it. It is evident therefore that herd immunity to a particular bacterial disease does not necessarily involve the resistance of each of its constituent members. As with the individual, a herd may be relatively immune because of its habits, its environment, or its mode of living. The relative

immunity to certain microbial diseases enjoyed by some herds of naturally susceptible individuals is obviously dependent upon environmental factors. Examples of this type of herd immunity are (*a*) the freedom from plague of human communities where the association of man, rat and flea is not sufficiently intimate to permit the infection to spread; (*b*) the freedom from typhus fever assured by the absence of gross overcrowding and the relative absence of the body louse, and (*c*) the freedom from malaria in temperate climates resulting from the inability of the causal agent to develop in the body of the mosquito below a certain average temperature. Certain diseases that are peculiar to certain climates, such as African sleeping sickness, or are particularly favoured by certain climatic conditions, afford other examples of this type of herd immunity. Finally, further examples are to be seen in certain diseases that are peculiarly favoured by certain occupations, such as consumption among grinders, flint-knappers, stonemasons, and coal-miners; glanders among farriers and grooms, and anthrax among wool-sorters, butchers, and cowherds.

In general, the methods of herd immunization are similar to those of individual immunization; but there is one method that differs essentially from any form of acquired individual immunity. It is a practical illustration, under natural conditions, of Darwin's conception of the survival of the fittest, and is shown by the weeding out of susceptible individuals in successive generations by disease and death. The result of this process is a progressive increase in the general level of herd resistance, until ultimately the disease can no longer spread among the herd and it becomes immune. This method of herd immunization is in progress at present in the British Isles in relation to consumption, and to tuberculous infections of other parts of the human body.

CHAPTER VI

PROPHYLAXIS AND THERAPY

THE healthy human body possesses wonderful defensive and recuperative powers; but occasions arise when, for a variety of reasons, the defences are unable to resist the bacterial invasion, or toxæmia, in the absence of some help from external sources. In many cases medical science is able to supply this assistance in

the form of diagnosis and treatment. Diagnosis rightly comes first, because until the nature of the causal agent is known the appropriate specific treatment cannot be given. A method of treatment that is efficacious against one germ may be valueless against another, or even harmful to the patient, so that it is of vital importance to establish the correct diagnosis as soon as possible. Often this takes time. The pathogenic germs are not provided with identity discs, and they are frequently indistinguishable under the microscope, almost identical in colony form, closely similar in their chemical activities, and only separable by delicate laboratory tests that require time for their accurate performance. No doctor can diagnose any human bacterial disease with certainty without the aid of a medical colleague in a bacteriological laboratory, because the absolute diagnosis of any such disease depends upon the isolation and identification of the germ that is responsible. In order to obtain this help the doctor may have to collect a number, sometimes a large number, of specimens of pathological material from the patient. The examination of only a single specimen often gives misleading results. Unfortunately, some patients—or their relatives—object to the collection of multiple specimens. "Leave the patient in peace" is their cry, and they expect the doctor to make a correct diagnosis and give the proper treatment with the same ease that the conjuror produces rabbits out of his hat. It cannot be overemphasized that germs are independent, living things, varying as much among themselves as we do, and that the identification of a particular germ may therefore take days, or even weeks, of patient and careful study. However, the problems of the diagnosis of bacterial diseases, fascinating as they are, do not come within the scope of our survey, and are mostly of such a highly technical nature that only the trained and experienced bacteriologist can appreciate them.

The treatment of bacterial diseases of man in general falls into three categories: (*a*) nursing, (*b*) drugs, and (*c*) specific bacteriological remedies. With the first two categories we are not concerned here, except to say that careful and intelligent nursing is probably the decisive factor in recovery in many cases. Rest of the part, or the whole, is Nature's prescription for most of the diseases to which man is subject, and while it is not possible to give complete rest to vital organs like the heart, brain, lungs, and kidneys, which have a continuous duty to perform, intelligent nursing can reduce to a minimum the strain imposed

upon them by disease. Drugs are chiefly of use as an adjunct to proper nursing. They help to keep the diseased tissues at rest, to tone up the general bodily activities, to soothe the patient, and to promote the elimination of waste and poisonous matter present in the body. When given under proper medical supervision they are of value; when taken indiscriminately in the form of patent medicines they are generally harmful.

The specific bacteriological remedies, whose use enables the doctor to strengthen the defences of the body and carry the war into the enemy's camp, may be either (*a*) chemical, or (*b*) biological (*i.e.*, produced by living matter) products. A book could be written upon the use of chemical substances in the treatment of bacterial diseases, but we must confine ourselves here to a few examples. Quinine is a valuable remedy for malaria, and even more valuable as a specific protector against malarial infection. Prevention is always better than cure, and most of the substances that we shall consider are far more effective as preventive than as therapeutic agents. Prevention, or prophylaxis (pronounced proffylaxis) as it is technically called, aims at making the individual immune before he runs the risk of contact with a particular pathogenic germ. Therapy, or treatment, aims at curing him after the germ has already attacked him. If we can effectively protect an individual we know that he is safe; we can never be sure that any treatment will be successful.

There are certain organic compounds of arsenic that are specific therapeutic remedies for one form of human anthrax, and are of great value in the treatment of syphilis and certain other microbic diseases of man. Acetylsalicylic acid (better known under its trade name of aspirin) is a specific remedy for acute rheumatic fever; but it rarely has any beneficial effect on the chronic "rheumatoid" and "neuritic" states of adults. The present consumption of aspirin, under various trade names, in this country is a staggering index of the credulity of the general public. The various trade derivatives of sulphonamide—the sulphanilamide compounds—have been shown recently to be specific therapeutic remedies for child-birth fever, pneumonia, gonorrhœa, and certain other bacterial diseases of man. All these substances are poisonous in some degree to the human organism, and their dosage needs to be carefully controlled by the doctor if they are to do good and not harm. Moreover, the same remedy may act differently in different individuals. The saying that one man's meat is another man's poison, is true of

any and every chemical substance, or drug, that is introduced into the human body in the treatment of bacterial disease.

The biological remedies are, without exception, used to induce a state of artificially acquired immunity to a particular pathogenic germ, and they are much more specific in their action than the chemical remedies. The immunity that is induced may be either an active or a passive immunity; but, whichever it is, it protects only against the particular pathogen and its close relatives. As I have already mentioned, it is not possible to confer upon any individual, either by natural or by artificial means, a general immunity against all the known pathogenic bacteria.

Bacterial antigens are present in every bacterial cell, and these antigens possess the property of stimulating the tissues of the human body to make specific antibodies. Bacterial toxins function as antigens and stimulate the tissues to make specific antitoxins. These antigens are more resistant to heat and to disinfectants than the living cells and we can destroy the latter without destroying their antigens. If, therefore, we kill a pathogenic germ and then introduce its dead body into the tissues of the human body, the tissues will proceed to make specific antibodies against the antigens of that particular germ. Obviously, as the germ is dead, it cannot invade the tissues or liberate toxins, so that no direct harm can accrue to the individual. This method of using dead germs is the foundation of that induction of a state of artificially acquired active immunity that is known to the public as vaccination, or treatment by vaccines. Let us consider a hypothetical case in order to see how the method works in practice. Mr. A. has been troubled for some time with recurrent boils. His doctor has corrected his diet, advised him about some much-needed exercise, regulated his sluggish bowels, prescribed tonics, and given him local treatment for the boils, but still they continue to come. Finally he decides to try a vaccine and sends him along to the nearest bacteriological laboratory. The bacteriologist removes a spot of pus from one of Mr. A.'s boils and cultivates from it a particular germ which, from past experience, he knows is the causal agent of Mr. A.'s condition. He reports his finding to the doctor and is asked to prepare a vaccine. He thereupon kills his culture of the germ, either by heating it to a temperature that he knows will kill the germ without destroying its antigens, or by treating it with a selected germicide, and suspends the dead germs in a sterile fluid that has no irritant action upon the tissues of the human body. This

suspension is the vaccine that Mr. A.'s doctor proceeds to inject in carefully regulated doses and at regular intervals into Mr. A.'s tissues. The vaccine may be successful or it may not; the result depends upon the soil, *i.e.*, the reactive capacity of Mr. A.'s tissues. If the vaccine (pronounced vakseen) is successful, Mr. A. rapidly acquires a specific immunity to the germ and his boils disappear. If it is not successful, it does no harm. The discerning reader will here object that Mr. A. has had the living germ in his body for a considerable time and has apparently not acquired any immunity to it. Why, then, should the introduction of the dead germ lead to the production of the requisite state of immunity? The answer is that, prior to the vaccine treatment, Mr. A.'s tissues had struck a balance with the germ and their reactive powers had become sluggish in consequence. The germ was held in check to the extent that its activities were localized to the boil and it was unable to produce a spreading, or a generalized, invasion of the body, but the tissues were too tired, or apathetic, to storm it in its local entrenchments. Nature had established a good state of parasitism, although the balance was slightly in favour of the germ. When the dead bacteria were artificially introduced into tissues that had had no previous contact with the germ, they immediately commenced to react specifically to the bacterial antigens. Their reaction, coupled with the outpouring of specific antibodies into the blood-stream, aroused the invaded tissues from their lethargy and enabled them to annihilate the germ. This is an example of successful vaccine treatment; but only a small proportion of the vaccines that are annually injected into patients in these islands is as successful. A vaccine can only be successful if the individual's tissues are capable of reacting to its stimulus. Neither the doctor nor the bacteriologist has any means of assessing the reacting power of the tissues of any person to any bacterial vaccine, except by the method of trial and error. Many members of the medical profession expect far too much from vaccine treatment, and their lack of judgment is apt to prejudice the public against the use of bacterial vaccines.

We have just considered an example of treatment by vaccine. Let us now consider an example of vaccine prophylaxis, which is by far the more effective method of using bacterial vaccines. Mr. B. is shortly leaving England to take up a post in the Far East. In the region to which he is going typhoid fever is prevalent, because of the absence of sanitation, the prevalence of

flies, and the lack of any control of the local water supplies. He is therefore certain to make contact sooner or later with an infecting dose of virulent typhoid fever bacilli. What can he do to protect himself against this attack? He consults his doctor, who advises him to have injections of a vaccine of *B. typhosus* in order to acquire an active immunity to it. Mr. B. wisely has the vaccine, and some months later arrives at his post to find an epidemic of typhoid fever devastating the local population. He takes no special precautions about his food, except to screen it from flies, or about the water he drinks. He picks up numerous doses of *B. typhosus*, but, as he is already immune against that germ, these doses merely strengthen his immunity, and he continues serenely at his post, the envy and admiration of the local populace, who have not been blessed by the practical application of one of the most valuable discoveries of medical science. During the Boer War, 1898–1902, the British Army in South Africa lost more men from typhoid fever than from all other causes put together. During the World War, in 1914–18, thanks to the prophylactic anti-typhoid inoculation of all men proceeding on active service from these islands, the incidence of typhoid fever among our troops in all theatres of war was negligible. Not every individual will react satisfactorily, however, to this vaccination. In prophylaxis, as in therapy, the soil is the determining factor in the success or otherwise of the vaccine.

Used intelligently, bacterial vaccines are a valuable adjunct to the weapons with which the doctor seeks to control bacterial diseases among his fellows; but their use can be abused. They have only a limited application in the treatment of established bacterial diseases; their main benefit is secured by their employment as prophylactic remedies. There is an old saying that the cure for a dog-bite is to swallow a hair of the dog that bit you. Our forefathers could never have visualized the modern use of bacterial vaccines as curative agents, but they foretold their use in this saying. The employment of bacterial vaccines for curative purposes is, however, of no more value than the swallowing of the dog's hair, except in a limited number of bacterial infections and in carefully selected cases of those infections. Unfortunately, bacterial vaccines are unwarrantably popular nowadays, both with the general public and with some medical men. They are easy to give; the doctor obtains them ready-made; the patient gets a psychological kick out of the injections—which often increases in proportion to the price he pays for the vaccine—and

they are supposed to replace the tiresome restrictions on diet and modes of living that are still effective lines of treatment, but are unpopular in this free age. There is little doubt that many worthless vaccines are annually injected into the inhabitants of the British Isles. The reader may feel slightly scandalized by this assertion, although he has no need to be. It may be an unfortunate state of affairs, because it implies an ignorance of the fundamental principles of Bacteriology and Immunity; it is not a scandalous one, because it is founded on the conscientious, though erroneous, belief that a vaccine must be efficacious because it is a vaccine. This misuse of bacterial vaccines is harmless even though it does no good, which cannot be said for either the drink or the patent-medicine trades, each of which flourishes with impunity in this country.

A bacterial toxin also functions as an antigen, and it can be obtained free from the bacterial cells by various laboratory procedures. If, for example, the bacteriologist cultivates *B. diphtheriæ* in a certain liquid, the germ makes its toxin just as it does in the human body, and the toxin diffuses out into the surrounding liquid. By filtering the liquid through a layer of porcelain, the pores of which are too small to permit the diphtheria bacillus to pass, the toxin can be separated from the bacterium. This crude toxin can then be purified and concentrated until the residual liquid consists of almost pure diphtheria toxin.

For every poison, chemical or bacterial, there is a minimum limit to the quantity that is poisonous for the average individual. Prussic acid is one of the deadliest inorganic chemical poisons known, yet it can safely be prescribed as a useful medicine, if the dose is kept below a certain limit. Arsenic is a deadly poison, but it is also one of the most valuable tonics we possess when its dosage is controlled. Similarly, it is possible to give people small doses of diphtheria toxin without making them ill. As the toxin is also an antigen, such doses will stimulate the tissues to make specific antitoxin, and the cumulative effect of repeated doses will be the production of an active acquired immunity to diphtheria toxin. The diphtheria bacillus can only cause disease in man by virtue of its toxin, so that an individual who is protected against this toxin is immune to diphtheria. The active immunization of children against diphtheria is one of the many triumphs of medical science that the public fails to utilize, either through ignorance or indifference. Diphtheria is still a very

dangerous and prevalent disease of childhood, but its incidence could be reduced to negligible proportions if parents would consent to the immunization of all children below the age of five years.

Active immunization by repeated small doses of bacterial vaccine, or toxin, is essentially a preventive measure. It is of no value, and may indeed be harmful, in the treatment of acute bacterial disease. The tissues require time in which to react to the stimulus of the vaccine, or toxin, and make the specific antibodies, or antitoxin. When a person is already ill and the body-tissues are fighting hard to check a bacterial invasion, or to neutralize a toxæmia, the injection into the tissues of additional bacterial antigens, whether they are inherently toxic or not, may be sufficient to tip the balance over against the patient. The time factor is therefore the determining one in the choice of methods of immunization. If the individual has been parasitized for weeks or months and a balance has been struck between his tissues and the parasite, active immunization by the injection of a bacterial vaccine may be tried as a curative measure. In the acute stage of any bacterial invasion, or toxæmia, any attempt to procure active immunization will throw too great a strain upon the labouring tissues. The tissues of the human body require several weeks to produce the necessary immunity to the typhoid fever bacillus, or to diphtheria toxin, so that any individual who is to be actively immunized against typhoid fever, or diphtheria, must be given the appropriate injections several weeks before he is likely to be exposed to the risk of infection.

When diphtheria toxin is injected into the human body the tissues make the specific antitoxin and pour it into the blood-stream. Exactly the same process occurs when the toxin is injected into the tissues of a suitable animal, such as the horse. The horse's blood soon contains a large quantity of diphtheria antitoxin and, if some of the blood is drawn off from one of the large veins of the animal under strict antiseptic precautions, the cellular elements of the blood can be removed and the remaining fluid portion will be rich in specific antitoxin. This fluid portion can then be concentrated and purified until it consists of practically pure antitoxin. Now, when Dr. C. was called to the bedside of John Bull's little sister, who, you will remember, contracted a very severe infection with *B. diphtheriæ*, he took with him in his black bag—all doctors are supposed to carry black bags—some phials of diphtheria antitoxic serum. As soon as his clinical

examination showed him that he was most probably dealing with a case of diphtheria, he injected some of this serum into his little patient and thereby saved her life. He also took a swab from her throat and sent it to the laboratory, in order to establish the absolute diagnosis of diphtheria; but he did not wait for the laboratory report on this swab before he gave the serum, because every minute was precious in the struggle between life and death, and if the bacteriologist found the infection to be other than diphtheria, no harm would be done by giving the anti-serum. He knew that if the condition was diphtheria, an unknown quantity of the deadly toxin was already circulating in the child's blood, and threatening to paralyse those vital centres in the brain and heart on whose continuous function her life depended. He knew that the injection into one of her veins of a sufficient quantity of the specific anti-serum would neutralize that toxin, and give her tissues the necessary respite and assistance to overcome the toxæmia. Fortunately, Dr. C. is one of many thousands of practitioners in these islands who know the value of diphtheria anti-toxic serum, and are ready to use it in every suspect case of diphtheria.

This method of utilizing the immune serum of an animal in the treatment of human bacterial disease is known as passive immunization, because it is evident, from the example given, that the tissues of the recipient play no part in the immunization process. The horse was actively immunized; the child received the benefit of that immunization. Passive immunity is secured immediately the specific anti-serum is introduced into the body. There is no time lag while the tissues are reacting, because that reaction has already taken place outside the patient's body. It will be obvious, therefore, that passive immunization is the ideal method for the treatment of acute bacterial invasions and toxæmias, when the patient's tissues are fighting desperately and time is of vital importance. There are, however, limitations to the use of this method at present, because medical science is only able to provide specific antibacterial and anti-toxic sera for a small number of bacterial diseases. The fault lies either in the biological constitution of the bacteria themselves, or in our inability to find a suitable species among the lower animals that will react satisfactorily to the germs, or their products. Nevertheless, brilliant results have already been obtained. The death rate of untreated diphtheria is over 80 per cent.; but the use of the specific anti-toxic serum has reduced it to about 5 per cent.,

and anti-serum treatment, combined with the universal active immunization of susceptible persons, could eradicate the disease from this country. The mortality from untreated tetanus is quite as high, if not higher, than that of diphtheria, and the specific anti-tetanic serum is powerless to effect a cure once the disease is established. If the anti-serum is given promptly, however, before the signs of the disease have appeared, it acts as successfully as diphtheria anti-serum. Tetanus generally results from the contamination of a wound with soil, especially manured soil, dust, and dirt. During the first two years of the war of 1914–18 there was a high death rate from wound tetanus among the British troops in France; but the disease was practically unknown in the last year of that war, after the routine practice had been established of giving every wounded soldier a prophylactic injection of anti-tetanic serum as soon as he reached a dressing-station.

Diphtheria, gas gangrene, tetanus, pneumonia, scarlet fever, erysipelas, childbirth fever, anthrax, and one form of dysentery, are bacterial diseases of man for which specific anti-sera of curative and/or protective value are now available. Diphtheria, tetanus, and scarlet fever are toxæmic diseases against which susceptible persons can be actively immunized by repeated injections of the specific bacterial toxins. Typhoid and paratyphoid fevers, dysentery, cholera, plague, and possibly tuberculosis, are diseases against which susceptible individuals can be effectively immunized by bacterial vaccines.

The following illustration of a hypothetical event may enable the reader to grasp clearly the value of an effective combination of the methods of artificial immunization with bacterial products. Larning is a public school with a resident population of some 500 boys. During the autumn term, after a dry and dusty summer, diphtheria breaks out in the school. The school doctor realizes that, unless the outbreak is rapidly controlled, it will mean a dangerous illness for many of the boys and necessitate the closing of the school. He orders the immediate quarantine in the school sanatorium of every clinically recognizable case of the disease. Any boy complaining of slight sore throat, or who is feeling unwell, is segregated, and his throat and nasal passages are examined bacteriologically for the presence of *B. diphtheriæ*. Every boy in whose upper respiratory passages the bacillus is found receives a prophylactic injection of the specific anti-serum, and every case of the disease is promptly given an adequate dose

of the serum. The whole school, including the masters and the rest of the staff, is then subjected to a double examination. Swabs are taken from the throat and nasal passages of every person on the school premises, or who regularly visits the premises, *e.g.*, tradesmen. Every person is given a small injection to find out whether he is naturally immune or susceptible to diphtheria. This is known as the Schick (pronounced shik) test, and is the most valuable test we possess for the control of epidemic diphtheria. A person who gives a positive reaction to this test is susceptible to diphtheria; one who gives a negative reaction is immune to the disease. As a result of these two tests, the school doctor is able to place all the school personnel in one of four groups:—

Group 1. Schick positive reactors, from whose noses or throats the bacteriologist has cultivated *B. diphtheriæ*. These are incubating cases of the disease, and are promptly despatched to the sanatorium and given a prophylactic dose of the anti-serum.

Group 2. Schick positive reactors, who are not harbouring *B. diphtheriæ*.

Group 3. Schick negative reactors, who are not harbouring *B. diphtheriæ*.

Group 4. Schick negative reactors, from whose noses or throats the bacteriologist has cultivated *B. diphtheriæ*.

The persons in Group 2 are susceptible to the disease, but have not yet contracted an infection. The doctor therefore proceeds to immunize them by repeated injections of the specific diphtheria toxin. The persons in Group 3 are naturally immune and require no treatment. The persons in Group 4 include the contact and true carriers of *B. diphtheriæ*, and somewhere amongst them is the carrier who was responsible for the outbreak of the disease. The contact-carriers are separated from the true carriers by repeated examination of swabs of their throats and nasal passages over a period of several weeks. The contact-carrier only harbours *B. diphtheriæ* for a few days, whereas the true carrier harbours the bacillus for months or years. The separation of these two classes is therefore essentially the work of the bacteriologist. When the true carriers have been identified, the doctor is faced with the very difficult problem of ridding them of the germ. This may necessitate vaccine treatment, local disinfectant treatment, and, as a last resource, the removal of their tonsils. Finally, each patient after recovery has to be examined to see (*a*) whether

he has acquired an immunity, and (*b*) whether he is a convalescent carrier of *B. diphtheriæ*. Any patient who has not acquired immunity is actively immunized, and every convalescent carrier is kept in quarantine until he ceases to harbour the bacillus, or until the germ has been eradicated by treatment. The school milk supply is also examined by the bacteriologist for the presence of *B. diphtheriæ*, because the epidemic might have been caused by the contamination of the milk by a carrier on the farm, or in the dairy, from which the school is supplied. The result of the prompt and skilful work of the school doctor is that the outbreak is restricted to a few cases, all of whom recover, and that the school is protected from any more outbreaks of diphtheria for a considerable period. If the school authorities are sufficiently intelligent to demand that every new boy, master, or other member of the staff must be tested for his immunity to diphtheria before entering the school, and every susceptible individual must be actively immunized before he is admitted, the school may be kept permanently free from the disease.

CHAPTER VII

STERILIZATION AND DISINFECTION

MUCH can be done to protect the individual and the community against bacterial attack by the maintenance of a satisfactory standard of hygiene, and by the systematic destruction of those pathogenic germs that are capable of prolonged survival outside the human and animal body. Cleanliness of the individual and of the herd is a safeguard against bacterial attack. The plentiful and regular use of soap and water is far more efficacious than the occasional application of the most powerful disinfectant. Sanitation is an index of the intelligence and education of a population, and the more efficient it is, the greater is the freedom of the community from outbreaks of bacterial disease. The proper collection and disposal of human sewage, of household garbage, and of certain trade wastes, abolishes the lurking-places of many pathogens. But, to achieve their maximum effect, these measures require to be supported by an enlightened public opinion, and by the active co-operation of the citizens. The British public at present lags far behind its health and sanitary services in a proper appreciation of the value of communal cleanliness

and tidiness. The disgraceful litter that is everywhere visible at holiday times in our parks, on our sea-side beaches, and around any country beauty spot, indicates that the public in general is ignorant of, and indifferent to, the need for order and cleanliness in our fight against bacterial diseases. Some persons seem to think that they have a right, as part of their heritage of freedom, to leave sewage, paper, empty tins and bottles, and uneaten foodstuffs on any land in this country. Such action indicates, however, only a total lack of consideration and natural good manners, and an unfortunate love of dirt and squalor, on the part of the individuals responsible. Dirt spells danger in connexion with the bacterial diseases of man, and litter of all kinds is essentially dirt. Even the authorities whose business it is to safeguard the communal health are too often complacently somnolent, because many Local Authorities have bye-laws against the deposition of litter, but few, if any, ever trouble to enforce them with sufficient rigour.

Some years ago, a little girl was running about barefoot on the beach of one of our sea-side resorts, when her foot struck against a jagged piece of glass, the remains of an empty beer-bottle that one of our free citizens had left on the beach. A deep, jagged wound in the child's foot resulted. Her mother bathed the wound in sea-water, bound it up with a " clean " handkerchief, and hurried her off to the nearest chemist to get it properly bandaged. Two days later the child complained that her foot hurt her and that her leg ached. Her mother saw that the skin around the wound was red and that several thin red lines in the skin were running from it up the child's leg. She bathed the wound in hot water and covered it with some boric lint that she had bought. That night the child was flushed and restless and slept very little, and the next morning she could not eat any breakfast. Her mother kept her in bed, hoping that the rest would do her good, but she grew so much worse during the night that her mother sent for the doctor early the next morning. When he saw the child he ordered her immediate removal to the local hospital, although his experience told him that he was probably too late, because the child was in the last throes of an overwhelming septicæmia. The doctors and nurses at the hospital did their utmost to save their little patient, but help had been too long delayed, and two days later she died. If the individual who left the beer-bottle on the beach had cut the child's throat, or strangled her, or beaten in her skull, he would have been hanged

for murder. He committed none of those crimes; but he left an empty beer-bottle on the beach!

Bacteria can be destroyed in a variety of ways. Sunlight, fresh air, rain, frost, and snow are all natural destructive agencies that are continually working to keep the bacterial population of the earth in check. Strong, direct sunlight is rapidly fatal to the vegetative cells of all the human pathogens, and even bacterial spores are destroyed by a sufficient exposure to it. The germicidal power of sunlight resides in its ultra-violet rays, the invisible short waves of light that lie beyond the violet end of the spectrum. These rays in sufficient dosage are inimical to all forms of life, but bacteria are possibly more sensitive to them than are the higher forms of plant and animal life. In small amounts they act as a powerful tonic to the human skin and, indirectly, to the body as a whole; but in excess they are harmful. The modern cult of sun-bathing may have disastrous results for some individuals, and no pallid city worker will benefit by suddenly stripping himself or herself virtually naked and lying for hours exposed to a fierce summer sun. The human body needs to be gradually acclimatized to the ultra-violet rays in the sunlight, and sudden, prolonged exposure of the bulk of the skin surface may stir up quiescent foci of bacterial disease in the body that would otherwise never have been aroused. The sun emits radiations that would rapidly make this planet completely lifeless, if they were not absorbed by the atmosphere that envelopes the earth.

Fresh air, with its high content of oxygen, is inimical to the vegetative cells of the pathogenic anaërobes. It also shortens the survival time of other pathogenic bacteria, partly by its drying action and partly by increasing their oxygen intake. Oxygen is the fuel of all life, and a certain minimal supply is essential for the maintenance of life in all its forms. Above a certain maximum, however, it acts like the forced draught of a furnace and leads to a rapid exhaustion of energy and the combustion of the cell. Bacteria can literally consume themselves in the presence of an excessive supply of oxygen.

Rain does not drown bacteria, because they do not possess air-breathing lungs that cease to function when they are filled with water, which is what happens when a human being is drowned. Some of the human pathogens die out rapidly in fresh water, but others survive for long periods. Heavy, continuous rain washes them out of the atmosphere, and so protects us from inhaling them. It also washes them off the surface of vegetation and

carries them down into the deeper layers of the soil, where they are less likely to make contact with man and animal. The chief beneficial anti-bacterial action of rain is that it lays the dust and prevents it from being blown about by the winds, to be inhaled by man, or deposited on his skin, his clothing, and his food. Dust harbours germs wherever it may accumulate, and a dry, dusty summer is always followed by epidemics of bacterial disease in the autumn months. A wet summer may spoil our holidays, but it safeguards us from bacterial attack. Dust is an irritant to the delicate membranes that line the human respiratory passages, and when these are mechanically and chemically irritated by inhaled dust they are less able to resist bacterial attack. Dusty trades show a much higher incidence of infections of the respiratory tract than the general public. The municipal water-cart that tours the streets, sprinkling them with water in dry weather, is therefore not wasting the rate-payer's water. It is protecting his health.

Frost and snow kill bacteria by their chilling action. Frost is the more potent germicide, and frosty weather is often noticeably free from outbreaks of bacterial disease, except among those persons who abhor fresh air and delight in over-heated houses, suffocating clothing, and overcrowding. There is no such condition as a " healthy fug ". Still, dry, cold air is a valuable tonic to the skin, and the human organism can tolerate intense degrees of cold under these conditions. Cold, damp winds are harmful and predispose to infections of the respiratory tract. Draughts of air are harmful because they lead to irregular chilling of the body, which in turn lowers the local resistance of the tissues. Wind, whether it be cold and damp or hot and dry, is generally an ally of the germ. It disperses bacteria, raises them into the atmosphere where we may inhale them, and lowers our local and general resistance to their attack.

Bacteria can be destroyed artificially by (*a*) physical, or (*b*) chemical means. The physical methods of destruction embrace the controlled application of the natural germicidal forces of heat, light, cold, and drying. Heat is the most valuable of these forces. Burning destroys all bacterial cells and spores, just as it destroys any other organic matter, and it is the simplest and most effective way of disposing of any combustible material that is contaminated with pathogenic bacteria. In the home it is a wise precaution to burn all waste that can conveniently be burnt on the kitchen fire, in the boiler of the central heating system, or in

the garden incinerator. Food waste is always better burnt than tipped into the dustbin. If it is put in that receptacle, it should always be carefully wrapped up in newspaper or brown paper. The average household dustbin offers a fertile field for bacterial colonization, especially if, as often happens, it is not regularly cleaned out and disinfected. Dry heat, short of burning, will kill the vegetative cells of most bacteria; but bacterial spores are much more resistant, and some can withstand temperatures up to 175° C. for several hours. In any case, dry heat is not a practicable method for the destruction of bacteria in the home or the workshop. Steam, especially when it is under pressure, is a most efficient germicide. Exposure to live (*i.e.*, not under pressure) steam for 30–60 minutes will kill all bacterial cells, and many spores, wherever the steam can penetrate. Unfortunately live steam possesses only a feeble penetrating power, so that bacteria hidden in the depths of non-porous materials may be unaffected by prolonged exposure to it. Steam under pressure has a much greater penetrating power and it rapidly destroys both cells and spores. Exposure to steam under a pressure of 20 lbs. per square inch for 20 minutes will destroy every form of microbial life. Few households are equipped with the necessary apparatus for this method of sterilization; but it is employed with great success in hospitals, laboratories, schools, and other institutions, to sterilize bed-linen, towels, clothing, and other contaminated articles and fabrics.

Sterilization implies the complete destruction of all forms of microbial life in the article or material treated. Absolute sterility can only be secured by burning, by the action of steam under pressure, and by the prolonged action of powerful, corrosive chemicals. It can rarely be achieved in the home and the workshop; but it is rarely necessary. A good margin of safety is provided by degrees of sterilization that fall short of the absolute, because the pathogenic germs are much more sensitive to artificial destructive agencies than the saprophytic ones. Proper cooking of foodstuffs in the home makes them sufficiently sterile to be eaten with impunity, even though they were heavily contaminated with bacteria prior to cooking. In order to obtain this effect, however, an adequate degree of heat must be applied for a sufficient length of time. Heat takes several hours to penetrate through a large joint of meat, for example, and the outer layers may be cooked and sterile while the meat around the central bone is raw and heavily contaminated. Half-cooked, or

underdone, meat may be dangerous, if it has not been obtained from a perfectly healthy animal and stored and retailed under strict conditions of cleanliness and fly-screening. Boiling rapidly sterilizes liquid foods. *B. tuberculosis* in cow's milk is killed by boiling the milk for 5 minutes, or by keeping it just below the boil for 15 minutes.

Strong sunlight rapidly kills the human pathogens, but our annual quota of it in these islands is too short and too irregular to enable the housewife and the manufacturer to utilize it as a means of sterilization. Bright, diffuse daylight is inhibitory to the pathogens, however, and the house or the workshop that is light and airy is much safer than a dark, ill-ventilated one. Plenty of fresh air and light are essential for the successful resistance of the human body to bacterial attack.

Cold retards bacterial activity; but it is not of much value as a sterilizing agent, because many pathogenic bacteria can resist severe and prolonged degrees of cold. Some bacterial spores, for example, can withstand long exposure to the temperature of liquid air, and comparatively delicate pathogens can survive freezing for long periods. Indeed, freezing tends to preserve bacteria by slowing down their vital processes and by protecting them from germicidal agencies. The home refrigerator does not sterilize the food stored in it; it only prolongs its eatable life by inhibiting the injurious activities of the contaminating bacteria. When the food is brought out into the warmer air of the house it often decomposes rapidly, because the bacteria develop with increased activity after their period of enforced inactivity. Chilled and frozen food should therefore be eaten immediately after its removal from the refrigerator, or cooked immediately and then, if not eaten at once, carefully covered to protect it against flies and wind-blown dust. The home refrigerator can be a danger rather than an asset, if the housewife is ignorant about its real action upon bacteria. The claims made for it as a sterilizing agency by some vendors are based upon a painful ignorance of the elementary principles of bacterial destruction.

A large number of chemical compounds are now marketed as " antiseptics ", " disinfectants ", or " germicides ", and their sale is secured by clever and intensive advertising. There are chemical substances that are efficient germicides; but their number is limited, and many of them are too irritant or corrosive to be of much practical value. The terms " antiseptic ", " disinfectant ", " germicide ", and " deodorant " are not synonymous

and interchangeable as many of the vendors seem to think, and as they wish the public to believe. An antiseptic is a substance that inhibits bacterial activity. The bacteria are not destroyed by it, or even permanently injured, and as soon as the antiseptic is removed, or its action has ceased, they resume their activities unimpaired. Moreover, no antiseptic exerts an equal inhibitory action upon all the different species of the pathogenic bacteria. A particular antiseptic may completely inhibit one species, only partially inhibit another, and exert no inhibitory effect at all upon a third. There are degrees of antisepsis, just as there are degrees of bacterial virulence and host resistance, and it is merely a confession of ignorance for the vendor of an antiseptic to claim that it is 100 per cent. effective against all the pathogenic germs. Many of the marketed antiseptics are not more than 50 per cent. effective.

A disinfectant is a substance that destroys bacteria and inhibits their action. Under suitable conditions and in sufficient strength it destroys them; in weaker strength and under less satisfactory conditions it only inhibits their activities. Every disinfectant is therefore also an antiseptic, but an antiseptic is not a disinfectant. A germicide is any substance, or property, that kills bacteria. A disinfectant can only act effectively under suitable conditions, and these vary for each disinfectant and for different species of bacteria. No single disinfectant is obtainable that is 100 per cent. effective against all the known species of pathogenic bacteria. A few are sufficiently potent to kill most species under widely varying conditions of application, but many are so specific in their action that they are of little value for general use in the home and the workshop. The chief factors that govern disinfection are (*a*) the nature and concentration of the disinfectant; (*b*) the nature and number of the bacteria to be destroyed; (*c*) the temperature at which disinfection takes place; (*d*) the time of exposure, and (*e*) the nature and composition of the environment in which the process takes place.

Most chemical disinfectants act best in watery solutions. Some act best in strong, others in weak, solutions. We speak of the quantity of the disinfectant in solution as the concentration of the disinfectant. Every disinfectant, with the exception of carbolic acid, loses much of its power in the presence of a mineral or vegetable oil, so that oily solutions of disinfectants are only feebly germicidal, no matter how cleverly they are advertised. The mineral acids, sulphuric, hydrochloric, and nitric, are powerful

disinfectants in strong concentrations and efficient antiseptics in high dilutions, but they are so corrosive and irritant that they can rarely be used as disinfectants. Carbolic acid exerts its maximum disinfectant action at a concentration of 5 per cent., and stronger concentrations are less effective. This concentration is far too strong for human use. The intact skin will only tolerate a 1 per cent. concentration for a short time, and the delicate lining membranes of the external body cavities cannot tolerate that concentration. The weak tincture of iodine (Tr. iodi mitis) is a valuable disinfectant for application to wounds of the skin, and a small bottle of it should be kept in every home and workshop; but applied to the delicate covering membrane of the eye, the conjunctiva, it causes agonizing pain and does more harm than good. The series of chemical compounds, of which "Dettol" was the forerunner in this country, are probably the most useful for general purposes in the home and the workshop. They are good germicides and are non-poisonous and non-irritant to the tissues of the human body. Several of these compounds, with slightly different chemical constitution, are now on the market under various trade names.

Different species of bacteria vary widely in their resistance to the same disinfectant. Bacterial spores are always much more resistant than the vegetative cells, but some of these are remarkably tough. Five per cent. carbolic acid kills the causal agent of scarlet fever almost instantaneously, but *B. tuberculosis* can resist its action for several hours. The causal agent of typhoid fever is extremely sensitive to chlorine, dilutions of the order of one part of chlorine in a million parts of water killing it rapidly; but it is much more resistant to carbolic acid. Formalin, which is the trade name for a 40 per cent. solution of formaldehyde vapour in water, kills most of the known bacteria, but different species show wide variations in resistance to it. The vapour is an even more potent germicide, but its inhalation is rapidly fatal to man.

The size of the bacterial population to be destroyed may influence the disinfection process. Some disinfectants are relatively unaffected by the number of bacteria present and will destroy 100 million cells as readily as 100,000. Others are unable to destroy multiples of a maximum number of cells—*e.g.*, they will destroy 100,000, but not 1,000,000 cells.

Heat increases the speed and effect of every disinfectant, although occasionally it may have an unexpected effect on a

particular disinfection process, because it also increases the activity and multiplication-rate of the bacterial population. If it stimulates the bacteria at the expense of the disinfectant, it will have a reverse effect to that intended, because we apply heat in order to make the disinfectant action more rapid and more certain. Some disinfectants are more affected by changes in temperature than others, and some appear to have an optimum temperature for their effective action. Five per cent. carbolic acid at a temperature of 60° C. is a much more powerful disinfectant than at room temperature, and 1 per cent. carbolic acid at 100° C. is more potent than 5 per cent. at room temperature.

Every disinfectant requires a certain minimum time of application to produce its proper effect. This time is not constant for the same disinfectant; it varies according to the nature of the bacterial population, their number, the temperature, and the nature of the environment. Bacterial spores always require a much longer exposure than the vegetative cells. All the bacterial cells are not killed instantaneously on contact with the disinfectant, even though the bacteria are delicate and the disinfectant is powerful. Variations in resistance are shown by the individual cells. Some are killed immediately, some more slowly, some only after a relatively long exposure. The constitution of the environment in which the action occurs may greatly retard the action of the disinfectant, necessitating a greatly increased exposure. Most of the alleged disinfectant mouth-washes and dentifrices that are on the market fail to exert even an antiseptic action upon the germs in the mouth, because they are only in contact with them for a few minutes instead of the many hours that are required.

Every disinfectant requires a suitable environment in which to act. The best results are obtained when both the disinfectant and the bacteria are brought into contact in a watery environment. As a rule, however, this is only possible under artificial conditions in the laboratory. In actual practice in the sick-room, the home, and the workshop, the bacteria are protected by the organic and inorganic matter surrounding them. Most disinfectants lose much of their power in the presence of proteins, partly because they enter into inert combinations with the proteins, and partly because they cause the proteins to coagulate and form protective coverings around the bacterial cells. The human body is a mass of proteins, which explains why many

disinfectants that are quite effective in a watery environment fail to kill pathogenic germs in the human body. The destruction of germs within the body-tissues by chemical disinfectants is often an extremely difficult operation. Strong concentrations of the disinfectants cannot be used because they would seriously damage the tissues by their poisonous, or corrosive, or irritant action. Weak dilutions that are innocuous to the tissues are made inert by the tissue proteins, and by those liberated from disintegrated bacterial cells. The Staphylococcus is rapidly killed by high dilutions of carbolic acid in a watery environment, but it is more resistant in milk because the proteins of the milk protect it from the disinfectant. There are only a few chemical disinfectants that are really effective against bacteria in a proteinaceous environment. The claims that are made for many so-called disinfectants by commercial interests would be merely silly, if it were not for their misleading effect upon a public that is mostly ignorant of the elementary principles of disinfection. It is most unfortunate that a particular laboratory test of a disinfectant, known as the Rideal–Walker test, has been given semi-official approval in this country, because it is of little value as an accurate index of the potency of a disinfectant under practical conditions. By varying the conditions under which the test is carried out, or by failing to allow for variations in technique, a bacteriologist can obtain almost any result he pleases within limits. The test is merely a farce in the hands of an incompetent bacteriologist. Yet great play may be made in advertising a disinfectant that it has a certain "Rideal–Walker coefficient", and the public is led to believe that a high coefficient represents a potent germicidal action. Actually, the coefficient only applies to the highly artificial conditions under which the disinfectant was tested in the laboratory, and may bear no relation whatever to its potency under practical conditions in the home and the workshop. The reader would be well advised to ignore the "Rideal–Walker coefficient" when he is selecting a disinfectant, and confine his purchase to one that he has proved to be effective by the method of trial and error. Unfortunately, the English law of libel so carefully guards the vendors of worthless "disinfectants" that the bacteriologist dares not warn the public against them. If he mentions them by name in any public utterance or writing, he will probably be compelled to pay heavy damages.

It is obvious from what has been written that disinfection is

not a simple process, and that a chemical compound is not necessarily effective because it is called a disinfectant. Disinfectants that are to be used in the treatment of bacterial diseases of man require to be selected with the same care as any other medicament. If satisfactory results are to be obtained, the chemical composition of the disinfectant must be known, the bacterium that is to be destroyed must be identified, and the conditions under which the disinfectant will be required to act must be known and must be kept constant as far as is possible. The idea that any stuff labelled " disinfectant ", or " germicide ", will invariably act effectively is as erroneous as the popular superstition that 13 is an unlucky number.

We may sum up our observations on the subject of chemical disinfection by listing the more important characters that the ideal disinfectant should possess, bearing in mind, however, that the ideal is unattainable, because bacteria differ so widely in their powers of resistance, and because the conditions under which the disinfectant must act in practice are never constant.

1. It must have no harmful action of any kind upon any tissue of the human body.
2. It must mix with, or go into solution in, the blood and lymph.
3. It must not enter into combination with, or be affected by, any of the tissue proteins of the human body.
4. It must be soluble in water or in a saline solution.
5. It must certainly kill all the known pathogenic bacteria and their spores when these are implanted in the body tissues.
6. It must certainly destroy any bacterial population, irrespective of the number of individual cells in the population.
7. It must be tasteless and odourless, or have a pleasant taste and smell.
8. It must act effectively at all temperatures between 0° C. and 45° C. The normal temperature of the healthy human body is 37·5° C.
9. It must not deteriorate on keeping, must be unaffected by heat or cold, and must keep equally well in the light and in the dark.
10. It must be inexpensive, non-inflammable, and fool-proof.

The simplest and best disinfectant for home use is hot water and soap, combined with regular vacuum collection of household dust. Anyone who will take the trouble to examine minutely the contents of the average domestic vacuum cleaner will find

that a large proportion of the dust consists of organic matter. The dust from a three-months' collection in the author's home comprised grit from the streets, earth from the garden, a mass of shed hair from the heads of his wife and daughters, and a miscellaneous collection of fragments of organic matter from food debris, the human skin, and other sources. Few people are aware of the fact that the surface layer of the human skin is continually being shed in health and replaced by a fresh growth from the deeper layers. Pathogenic bacteria lurking in the folds and fissures of the skin are shed with the surface layers, and they are also ejected from the external cavities of the body by the reflex acts of coughing, sneezing, crying, and by the voluntary acts of talking and laughing. They find congenial conditions for their survival in the dust in dark places, and some of them find a food supply in the organic matter in the dust. The dusty home is a dangerous home. Water lays dust and prevents it from being stirred up and dispersed. Hot water destroys the more delicate and more dangerous pathogens, and soap facilitates their removal from a variety of surfaces. Regular scrubbing of floors, cleaning of carpets and rugs, washing of bed-linen, underclothes, and the human body, will keep the dwelling-house reasonably free from dangerous dust. Plenty of fresh air and light, the thorough cleansing of all food utensils, the screening of food, and the careful collection and disposal of all food debris, will reduce the opportunities for the survival of bacteria, and the insects and vermin that may harbour them. The clean and tidy housewife is one of the most important members of the national Health Service.

Minor injuries are of frequent occurrence in the home, especially when there are young children in the family, and in the workshop. Any breach in the continuity of the skin may be a portal of entry for pathogenic bacteria. Cuts, bruises, and abrasions, however slight they may appear to be, should therefore never be neglected. Every home and every workshop should have a small supply of sterile lint, a few bandages, and a small bottle of tincture of iodine. A drop of iodine applied to a cut, a midge-bite, or a needle-prick, may save a life. Most surface injuries will heal of themselves, if they are thoroughly washed in hot water, treated with iodine, and then protected from dust and dirt by a sterile covering. But iodine must never be applied to a burn or a scald. If it is a small one, dress it with castor or olive oil; if it is a large one, call in the doctor. As a

valuable alternative to bandages, the adhesive and antiseptic material, marketed under the trade name of "Elastoplast", can be used. Probably the best home treatment for a boil is to cover it with a bit of "Elastoplast" and then forget about it. If, after a day or two, it continues to intrude upon one's consciousness, go and see your doctor.

In place of the tincture of iodine, black iodine ointment can be applied as a dressing with good results. An occasional individual is extremely sensitive to iodine, so much so that the application of a small quantity to the skin brings out an intensely irritating rash. Individuals who are afflicted with this sensitivity would be well advised to consult their doctor about the local disinfectants that are available for their use.

CHAPTER VIII

COMMON INFECTIONS OF THE HUMAN SKIN

ALTHOUGH the skin is normally highly resistant to bacterial attack, occasions arise when, for one reason or another, bacteria penetrate its defences and cause trouble. Spreading invasions of the skin sometimes occur, but generalized invasions by bacteria are rare. Some of the ultra-microscopic viruses, notably the causal agents of measles and small-pox, have a predilection for the skin and constantly produce generalized invasions of it. Rarely, a generalized invasion by a microscopic fungus may occur; but, apart from these instances of virus and fungal disease, the natural resistance of the skin is generally strong enough to confine the microbial attack within local limits.

The resistance of the skin is, of course, intimately bound up with the general health and vitality of the individual. If the general health is poor, the resistance of the skin is correspondingly reduced. If the resistance of the skin is high, the general health and resistance of the individual are also good. A variety of causes may operate, however, to reduce the local resistance of the skin, independently of any alterations in the general health of the individual. Defective personal hygiene, resulting in the accumulation of dirt on the skin and the clogging of the pores with dried sweat and dirt; the excessive use of cosmetics, which also leads to the clogging of the pores, and the artificial removal of hair, either by mechanical or by chemical means, may reduce

the local resistance of the skin and facilitate bacterial attack. Minor defects that are inherent in the individual may also predispose the skin to infection. Some persons have naturally dry skins that crack easily, especially in cold weather and after prolonged immersion in water. Many housewives complain of "chapped hands" during the winter months. The cracks and fissures that form provide an easy means of access to the softer and less resistant layers beneath the external horny layer, and are often the site of localized, chronic bacterial infections. The dryness of the skin is generally the result of disordered function of the grease- and sweat-glands, and may be localized, affecting only one region of the body, or generalized. Some persons, for example, perspire readily from their head and trunk, but only slightly, if at all, from their limbs. Some persons are afflicted with an excessive activity of the grease- and sweat-glands of their feet, which results in the production of objectionable odours that are distressing to sensitive individuals, and which makes the skin soggy and less resistant to bacterial attack. Some persons have inherently greasy skins, owing to over-activity of their grease-glands, and the excessive accumulation of the natural grease favours the deposition and establishment of bacteria. Individuals therefore differ widely in the natural condition of their skin, irrespective of any alteration in their general health and vitality. Whatever may be the natural condition of the skin, frequent and regular washing of the entire body with warm water and pure soap is the best protection against bacterial attack. I stress the need for using pure soap, because many of the cheaper, highly scented brands of soap that are now marketed are too caustic for sensitive skins. A pure soap contains only a minimal content of alkali, and therefore does not irritate the skin. No additional benefit will accrue from the use of the so-called "antiseptic" and "disinfectant" soaps, because every chemical disinfectant—with the possible exception of biniodide of mercury—loses much of its power when it is incorporated in a soap. As a rule, the incorporation of a chemical disinfectant in a soap merely makes the soap more irritant to the skin. In any case, soap is not used for its disinfectant, but for its detergent, action—*i.e.*, to remove the grease from the skin and allow the water to flush the skin surface and mechanically remove any particles of dirt and bacteria that may be present on it. Regular changes of underclothing, and proper laundering of clothing and bed-linen, are

also essential. Even to-day one still encounters in this country individuals whose acquaintance with a bath is practically limited to a birthday treat! There are still many cottages in rural districts that are not provided with proper facilities for the personal cleanliness of the occupants. Every person in this country ought to be able, with the minimum of inconvenience, to have a bath, or a complete wash-down of the entire body, at least once a week. A weekly bath is a necessity for adults whose occupation is of a clean and sedentary nature. Workers in dirty and dusty occupations and those who do hard manual work, should have the opportunity of a bath after each day's work. Children require more frequent bathing than adults, and infants require to be bathed at least once a day for the first year of life.

The commonest infection of the human skin, and probably the commonest bacterial disease of man, is the single boil. Most people are conversant with the character and appearance of this local skin lesion from personal experience, because very few individuals live to old age without suffering from a boil. Men are more often attacked than women, partly because they are more hairy, and partly because they are more exposed to minor injuries of the skin in the course of their work and their play. Adults are more often afflicted than children, again partly because they are more hairy. A boil most commonly starts in a hair-follicle, although it may also start in the duct of a skin-gland, or in any fissure, abrasion, or bruise of the skin. A bruise results from the rupture of one or more of the small blood-vessels in the skin, caused by sudden pressure, with the consequent leakage of blood into the tissues. The rainbow colours of a " black-eye " are produced by the chemical changes that occur in the free hæmoglobin while it is being broken down and removed by phagocytes. Free blood pigment in the tissues is treated by them as a foreign body, and the body does not rest until the offending material has been broken down and removed.

The causal agent of most boils is a spherical germ, known to bacteriologists as a Staphylococcus (pronounced staffillokokkus). This is a hardy germ that is capable of prolonged survival outside the human body in dust, in clothing, on foods, and on a variety of fomites found normally in the home and the workshop. As I have already mentioned, boils commonly occur on those regions of the skin that are normally hairy, particularly where the skin is subjected to any continuous slight pressure, irritation, chafing,

or slight injury. In men the common sites are the beard region, the back of the neck, the shoulders and the forearms. In women, the back of the neck, the shoulders, and the armpits in those who are forced by modern fashions to interfere with Nature, are most often affected. In both sexes the buttocks are a common site.

The sequence of events in the formation of a boil is remarkably constant. The staphylococcus is deposited on the skin in a variety of ways. Wind-blown dust; the wearing of dusty and dirty clothing; dirty finger-nails; droplets from the upper respiratory passages—in which the germ often lurks as a commensal—contacts with contaminated articles in the home and the workshop, and the application of cosmetics, are all possible means by which it is transported to the skin. It is then pushed into a hair-follicle, the duct of a skin-gland, or any breach in the continuity of the skin by the pressure of the clothing, the flow of perspiration, the muscular movements of the body, or the pressure of the fingers in the act of rubbing, or scratching, an itching spot. In the depths of a hair-follicle it finds congenial conditions for its development—warmth, absence of light, oxygen, moisture, and an abundant supply of rich food in the proteins and sugar in the tissues. What more could a staphylococcus want? It therefore rapidly settles down to its essential business of growth and reproduction. It is quite an accident that, in the process of playing its part in Nature's scheme, it creates conditions that are disturbing and injurious to the surrounding tissue cells. It merely reacts to the stimuli of shelter and sustenance. Some people are imbued with the notion that germs have a malevolent purpose. They believe that disease germs deliberately seek out their human victims, or lie in wait and pounce upon them. This idea is, of course, ridiculous. It is either purely by chance, or as the result of carelessness and ignorance, that the germ is brought into contact with its human host, and its behaviour when that contact has occurred is immutably fixed by natural laws.

The body quickly responds to the activities of the staphylococcus in the way that I have already described, so that quite soon a collection of pus occupies the bottom of the hair-follicle. The increased flow of blood into the tissues around the follicle produces a series of changes in the appearance of the skin. When an incompressible fluid is pumped into a firm, yet elastic, tissue, two changes take place—(*a*) the tissue swells out and its constituent elements become stretched and separated, and (*b*) the

internal pressure rises. Most chemical reactions are accelerated by heat, and the reactions that take place in the human body conform to this rule. Fever is the manifestation of Nature's way of increasing the internal temperature of the body, and the blood automatically shares in the general process. Owing to the increased temperature of the blood, and its local concentration in the tissues around the follicle, the local temperature rises until the skin surface immediately surrounding the follicle feels appreciably warm to the touch. The distended tissue expands in the only possible direction, outwards, and the skin is raised up around the mouth of the follicle. The red colour of the blood shows more and more clearly through the stretched skin, and the increasing pressure squeezes the sensitive nerve-endings in the affected area. The four cardinal signs of inflammation are pain, heat, redness, and swelling. They are all present in the boil. The distension of the skin at first closes the mouth of the hair-follicle, but, as the quantity of pus in the follicle progressively increases and the internal pressure proportionately rises, the pus is soon forced up the shaft of the follicle and appears at the surface as a yellow spot. In popular parlance the boil is now "ripe". It is certainly ripe for mischief, if it is subjected to meddlesome and ignorant interference. A golden rule in the home treatment of a boil is to leave it well alone. Attempts to squeeze out the "matter", often made with dirty fingers, or an even dirtier handkerchief, may result in the bursting of the walls of the follicle and the wide dispersal of the germs in the delicate, less-resistant surrounding tissues, not to mention the probability of additional germ infection. Many a deep-seated abscess, necessitating surgical intervention, results from such attempts.

Some years ago a girl, aged nine, was brought into a hospital in a dying condition. A bacteriological examination revealed that she was suffering from an invasion of her brain and spinal cord by a staphylococcus, which had also entered into, and was multiplying in, her blood-stream. She was a well-built and well-nourished child, and there was no wound in the skull, or any other visible injury, to account for her condition. She died on the day after her admission and, as the death certificate could not be properly filled in without a post-mortem examination, the coroner ordered an examination to be made to explore the possibility that the fatal infection was secondary to an injury, accidental or deliberate. The examination revealed that she

had a boil on her scalp, hidden by her hair, and a huge abscess between her scalp and her skull. This abscess contained so much pus that her scalp was literally floating on a thick film of it. The germs present in the abscess had been driven by the pressure of the pus through the tiny canals in the skull-bones—which house connecting blood and lymph vessels and nerves—into the cranial cavity, and they had multiplied rapidly and spread widely in the delicate brain-tissue. When the child's mother was questioned later, she said that she had noticed a "pimple" on her daughter's head, and that she had squeezed it to "get out the matter". If she had left that boil alone her daughter would have been alive to-day in all probability.

Treat a boil as you would a heap of explosive. If it is a small one, cover it with a strip of "Elastoplast", or a piece of sterile, dry boric lint, held in place with adhesive tape, or with a piece of sterile lint covered with iodine, or boracic, ointment, and forget about it. If it is a large one and painful, go and see your doctor. Don't squeeze it, or pick the head off with your finger-nails. Finally, don't worry about it. If it is a small one, there is no need to worry. If it is a large one, your doctor will do the worrying for you. That is what doctors are for, to worry over the ailments of their fellows, and most of them discharge the duty much more conscientiously than the public recognizes. No doctor worth his salt ever contentedly abandons his fight against disease, or sees Death claim a victim without feeling that he has failed in his trust. Experience may equip the good doctor with a necessary shield of apparent callousness; but that is merely a defensive camouflage, behind which his conscience is ever urging him on to give of his best in the service of his fellows.

The boil is produced by the bacterial invasion of a single follicle. It may happen, however, that many follicles are invaded simultaneously. The result of this multiple invasion is a carbuncle, which may be regarded as the father of all boils. It is less common but more dangerous than the boil, with a mortality rate that ranges between 5 and 10 per cent. of those attacked. The causal agent in the great majority of cases is a staphylococcus, and this germ is both toxic and invasive. It makes a powerful exotoxin, and probably an endotoxin also, and it is capable of producing a rapid, generalized invasion of the body. The amount of toxin absorbed from a boil is usually not sufficient to interfere appreciably with the patient's general health, but the carbuncle is always accompanied by a toxæmia

of varying degree. There is also always some leakage of the germs into the blood-stream, owing to the involvement of the cutaneous (skin) vessels in the destruction wrought in the tissues. In most cases the blood is able to destroy these germs, but occasionally some of them manage to settle down in various sites in the body and form abscesses that require surgical treatment, and, rarely, they may set up a fatal septicæmia. The extention and severity of the bacterial attack result in the destruction of a large amount of tissue, which forms a core of dead tissue in the centre of the carbuncle. Around this core there is a zone of acute inflammation with pus formation, and the blood-vessels in this area are plugged with coagulated blood. Owing to the loss of its blood supply, the overlying skin dies and sloughs away, leaving a ragged hole from which pus continuously oozes. Until the core of dead tissue has been expelled the carbuncle will not heal, and this process takes time. Home treatment of a carbuncle is never advisable; the condition is potentially too dangerous, and medical assistance should therefore be obtained as soon as possible. The common sites are the back of the neck, the shoulders, and the buttocks, but they may occur wherever there are hair-follicles. Carbuncles on the face are very dangerous when they are located near the nose and lips. Men are more often affected than women, and adults more often than children. The general mortality rate, apart from carbuncles on the face and scalp, is less than 5 per cent., but the disease is always associated with some lowering of the general health and resistance and with a variable degree of fever. The chief danger of a carbuncle is that it may pave the way for some more serious bacterial disease by reducing the patient's general resistance. The skin lesion may take several weeks to heal, even under prompt and efficient medical treatment, and during this time the individual is suffering from some degree of toxic absorption. It is surprising, however, with what good results the damage is repaired once the germs are destroyed and the dead tissue expelled. Cavities into which a large hen's egg could be introduced heal with a barely visible scar, and convalescence is rapid once the healing process has begun.

Minor septic infections of the skin, especially of the hands and feet, are common. They usually follow some injury, such as a cut, a bite, or a blood-blister. They often subside satisfactorily under the same simple treatment that cures a boil; but if they are still painful and throb after a day of that treatment, it is

wise to seek medical advice. Septic infections around the nails should never be treated at home. The common practice of attempting to cut corns at home, usually with a pair of dirty scissors, is responsible for many unnecessary septic infections of the toes and feet. It is usually cheaper in the long run to visit a reputable chiropodist. Corns are one of the most crippling and distressing of minor maladies, and it is a pity that the medical profession, as a whole, apparently considers them too trivial to warrant its interest and attention. The usual cause is the wearing of badly-fitting shoes and boots, and the modern fashions in feminine footwear must be a godsend to the chiropodist.

A common bacterial disease of the skin of young adults, especially males, between the ages of 17 and 25, is acne (pronounced akknee), better known under its popular name of "blackheads". The disease is largely confined to dark-haired, dark-complexioned individuals with greasy skins, and is primarily a temporary disorder of the grease-glands in the skin. The causal agent, *Bacillus acne*, normally leads a saprophytic existence in the ducts of the sweat-glands of most human beings. Acne is not a dangerous disease, and it is not associated with any lowering of the general health and vitality of the individual; but it is often a distressing complaint to sensitive persons, because the blackheads that are scattered over the forehead, face, and shoulders are plainly visible and detract from the personal appearance of the sufferer. These blackheads are really small plugs of solidified grease, containing *B. acne*, which distend the ducts of the grease-glands and are capped with a layer of dirt. Dirt, in the form of soot, smoke, and wind-blown dust, is continually impinging upon the exposed areas of the skin. The disease can only be effectively treated under medical supervision; but it offers the hopeful prospect that most victims grow out of it about the age of 25. Sometimes, however, the acne lesions become secondarily infected with the staphylococcus, especially when they have been meddled with by inexpert persons, and then the more dangerous condition of pustular acne develops. Instead of the dry, non-progressive acne pimple, small abscesses form around the blackheads, and when they eventually heal they leave disfiguring scars. As a rule, the natural resistance of the skin is able to keep the staphylococcal infection localized; but it is a septic condition and requires careful treatment under medical supervision. It

causes much distress to sensitive young women who are fond of dancing, and to men who are fond of swimming, because these pastimes expose their scarred shoulders to the public gaze. The best protection against pustular acne is scrupulous personal cleanliness, although sometimes a high standard of personal hygiene does not safeguard the unfortunate victim of acne from the super-imposed staphylococcal infection.

Erysipelas is the medical name for a spreading, inflammatory invasion of the skin by another spherical germ, known as the Streptococcus. It is a more dangerous disease than pustular acne and may, occasionally, prove fatal. Personal cleanliness does not necessarily give protection against it. Chance plays a large part in its distribution, and the victim is just unlucky to have made contact with the germ. In our grandparents' time the disease was much more dangerous than it is now. Little was known about germs in Victorian Britain—the Science of Bacteriology is not yet a century old—and many doctors refused to believe that there were any such things. Medical science now possesses effective remedies for this disease, and for most patients an attack merely means a few days in bed and a number of injections. Even so, erysipelas is potentially too dangerous a disease to be ignored, and the victim will do well to call in the doctor at once.

There is an old saying that a stitch in time saves nine. This is peculiarly applicable to human disease, whether of bacterial or other origin. An early consultation with the doctor may save weeks of suffering and ill-health, and sometimes makes all the difference between life and death. People forget that the doctor is human and fallible and that, unlike the watch-mender, he cannot open the case to examine the works inside. They defer consulting him until the last minute, and then expect him to work miracles. If they are slow to consult him, they are even slower to pay him for his services! The time factor is of vital importance in all bacterial diseases of man, and in most other diseases as well. It often takes time to establish the correct diagnosis; it always takes time for the correct treatment to take effect. If the doctor is given sufficient time it will usually be no fault of his if recovery does not occur. Moreover, if he advises a certain line of treatment, it is foolish not to give it a thorough and conscientious trial. It may be irksome, or distasteful, or frankly unpleasant. It may seriously interfere with one's conception of personal freedom and pleasure; but if it is worth while calling

in the doctor at all, it is worth while giving him a fair trial. I used to know a lady who suffered from chronic rheumatic trouble. She often consulted her doctor, and consistently poured the medicine he gave her down the sink with the remark that she did not believe in doctors! If any reader of this page has the same mentality, may I suggest that he or she should do their own doctoring, and leave the over-worked doctor to attend to those persons who appreciate his services and are ready to give them a fair trial.

CHAPTER IX

SOME INFECTIONS OF THE RESPIRATORY TRACT

THE human respiratory tract is a common portal of entry for pathogenic germs, and in most cases infection is transmitted by the droplet method. The common cold, influenza, pneumonia, whooping cough, diphtheria, scarlet fever, spotted fever, consumption, wool-sorter's disease, glanders, tonsillitis, mastoid disease, and sinusitis are bacterial diseases that take origin from infections of the tract. Measles, rubella (german measles), chicken-pox, mumps, infantile paralysis, glandular fever, and small-pox are virus diseases that begin in the tract. Actinomycosis is a fungus disease that often starts in the tract.

A brief description is necessary here of the structure of the nasal apparatus. At the back of the nose the nasal passages communicate with several air-spaces (or air-cells) that are hollowed out of the bones of the face and skull. These air-cells are the sinuses of the nose. There are two frontal sinuses, one on either side of the mid-line of the body, situated above the eyes; two antrums, one behind each cheek; a single sphenoidal sinus, right at the back and only separated from the cranial cavity by a thin plate of bone, and a group of ethmoidal sinuses in the roof of the nasal passages. A slender tube—the Eustachian tube—also runs from each side of the nose into each middle-ear. The function of this tube is to equalize the air-pressure on the drum of the ear, which would otherwise be blown inwards by the pressure of the external air. The sinuses also serve as air-pressure regulators.

The common cold is the commonest bacterial disease of the human respiratory tract. In the British Isles it is annually

responsible for an enormous loss in individual and national efficiency, for much serious ill-health, and for severe industrial dislocation and economic loss. Most persons, children as well as adults, suffer from one or more colds during the winter months, and no age and neither sex is exempt. Familiarity breeds contempt, and the common cold is so familiar to us that we are apt to make light of it, sometimes with serious consequences. The danger is always present that the nasal infection may spread into the nasal sinuses, the mastoid air-cells behind the ears—by way of the Eustachian tubes—the lungs, or the blood-stream. The nose has a very rich blood supply, as some readers may have had cause to know, and the richer the blood supply to any organ or tissue, the greater is the risk of invading bacteria entering the blood-stream. It is also true, however, that the richer the blood supply, the stronger the defence.

The causal agent of the common cold has not yet been identified. Some bacteriologists believe that it is an ultra-microscopic virus, and there is some evidence to support that belief; others believe that different germs can invade the nasal passages and produce a similar sequence of events in the individual. A cold often seems to start in the same way, and to follow a similar course, in the same person. Some persons start one with paroxyms of sneezing; some commence with a sore nose, or throat; some have shivering attacks and pains in the head and face, and some suddenly begin to " run like a tap " from nose and eyes. The sequence is roughly alike in different individuals. Two or three days of a thin, watery discharge from the nose and eyes, associated with a " thick-head ", a variable degree of fever, and a variable degree of malaise (*i.e.*, feeling ill). Then several days of a yellowish discharge, which progressively deepens in colour and thickens until it becomes gelatinous in consistency and, finally, a week or more of snuffling, nose-blowing, and throat-clearing to expel pellets of gelatinous material (mucus) that represent the subsidence of the infection.

The best treatment for a cold is two or three days in bed on a light diet containing plenty of fruit. Stuff a cold and starve a fever is a popular saying that has no justification in practice. The body should not be burdened with the strain of digesting heavy meals when it is mobilizing all its resources to combat a bacterial invasion. It has plenty of reserve food material stored up in its tissues to make it independent of outside supplies for a long time. Rest in bed is not considered to be a practicable

proposition, however, by many victims. The mother of young children, the wage-earner of the family, the doctor, the dentist, the business man, and many others all say that they cannot afford to go to bed with a cold—they must continue at their work and fight it out. Fighting a cold is a short-sighted policy, but most of us are guilty of it. Let us consider what fighting it out entails.

1. The individual in the active stage of a cold is a menace to the community. Every time he sneezes, or coughs, he sprays virulent germs around him. Every time he blows his nose he deposits enormous numbers of germs in an insanitary piece of material, with which he then contaminates his hands and his clothing, and which someone else has to wash for him. He is a dangerous focus of infection, a sower of germs that may be fatally virulent for someone with whom he comes into contact.

2. His defences need all the help he can give them, if they are to combat the infection quickly and successfully. Rest and warmth are what they need. Sudden changes in temperature from the warm room to the cold passage; from the office to the draughty tram or bus; from the cold street to the heated train, and back again to the street, impose severe additional strains on his body's defences, which cannot be evaded by wearing a heavy overcoat and winding a woollen scarf around his neck. Again and yet again his body's defences may triumph over the nasal infection in spite of all the unconscious assistance he gives to the invading germs; but the risk is not worth while, because a time may come when they break down, and the collapse will then be complete.

3. The individual runs the grave risk of picking up other virulent germs from his fellows while his defences are already endangered. A slight additional infection may be sufficient to decide the issue between recovery and prolonged ill-health, or death.

A few of our large industrial concerns, and some of our schools, realize that the common cold is often the precursor of more dangerous infections and is always an uneconomic proposition. These enlightened bodies prohibit any employee, or scholar, who has a cold from entering their premises, and if someone with a cold comes to the office, the workshop, or the school, he or she is promptly sent home again. In course of time, the knowledge that the common cold is one of our most dangerous infections, and most uneconomic, will sink into the

tional intelligence. When that time eventually arrives and becomes unfashionable, or unsportsmanlike, for the individual th a bad cold to be seen mixing with his fellows, the incidence the common cold will diminish and a huge burden of ill-health d financial loss will be lifted from the nation.

At present, medical science cannot offer any certainly effective eatment for the common cold. The number of alleged curative tent medicines is, however, legion. Many of them have a gue for a time, and are then relegated to the limbo of the rgotten. A few of them that are either palatable or nauseating pear to remain indefinitely in popular favour. The value of any of these patent remedies is in inverse proportion to the ne and ingenuity spent on advertising them. Some persons plicitly believe that by doing this or that, or by taking this or at, they can quickly cure their own colds. Faith can still ove mountains! A very popular fallacy is that whisky is a re. As alcohol in any form lowers the body temperature and tards the delicate reflex mechanisms on which all the functions the body ultimately depend, it is evident that in most cases e cold merely serves as an excuse for the whisky. The author s known several staunch teetotallers who turned to whisky as unfailing remedy at the first sneeze. Hot drinks of milk, uit juices, or one of the commercial preventives of the imaginary mplaint of night-starvation (whatever that may mean) are of lue in keeping the body warm, providing that the individual mains in a warm room or, preferably, in bed.

Many cases of sinus infection after a cold undoubtedly arise om a faulty use of the individual's nasal apparatus. It is ite a common practice for the individual to close both nostrils ghtly, take a deep breath of air in through the mouth, force it into the nasal passages, and then let go of the nostrils and llect the ejected matter in a handkerchief. The louder the umpet, the more gratifying is the feeling of a deed well done. et us apply a little elementary physics to this process. The sal passages are full of purulent matter that is loaded with rms. When the internal pressure in those passages is greatly ised by the common method of blowing one's nose, what ppens to this matter? What happens to any fluid under essure? It seeks the line of least resistance! In this case it nnot escape at once from the nostrils, because they are closed; cannot escape backwards into the mouth, because of the air essure. The only avenues of escape are the openings leading

into the sinuses and the tubes leading to the middle-ears! The proper way to blow the nose is to close one nostril at a time and then blow gently and steadily down the other one. Too vigorous blowing may still drive the pus back into the sinuses, or rupture one of the blood-vessels in the nose. Finally, use a paper handkerchief, or any piece of soft paper that can be burnt at once, when you blow your nose. The conventional pocket handkerchief should be conspicuous by its absence when colds are about.

Pneumonia may be the sequel to a neglected cold. The causal agent of this invasion of the lungs is most often an ovoid, or egg-shaped, bacterium known as the pneumococcus (pronounced newmokokkus). It is a dangerous disease at all ages, but especially for infants and old people. If it does not arise as a spread of germs from the nasal passages into the lungs during a severe cold, a cold may lower the resistance of the individual, and he contracts the lung infection from a carrier of the pneumococcus. Probably most cases of the disease are the result of droplet infection from a human carrier, and the person with a cold is often a temporary carrier of the pneumococcus. Direct infection of a susceptible person from a pneumonia patient is a comparatively rare event, and there is little danger attendant upon the nursing of a case. Human carriers of the pneumococcus are numerous, particularly in cold and temperate climates and during the cold, damp seasons of the year. The distribution of the germ among a community is favoured by the crowding together of people in enclosed spaces.

Pneumonia is not as dangerous a disease as it was a generation ago, because medical science has recently discovered effective remedies for it, but it is still one of the commonest causes of death in the elderly. It is also particularly dangerous to the alcoholic individual and to people whose vitality has been lowered by some pre-existing disease. Alcohol is a staunch ally of the pneumococcus, and recovery often depends upon the extent of the patient's previous addiction to alcohol. Recovery from an attack of pneumonia, or from a cold, does not confer any long immunity upon the individual, and no satisfactory immunity can be induced by artificial methods. Some persons may derive temporary relief from colds by a course of "anti-catarrhal" vaccine, especially when the vaccine is made from their own germs; but vaccines of the pneumococcus do not give protection against pneumonia, because the pneumococcus

is biologically incapable of stimulating the body-tissues to a sufficient degree.

Scarlet fever and diphtheria are analogous in that they are toxæmias and that the causal germs show a predilection for the tonsils and the contiguous regions of the mouth and throat. They are spread directly by droplet and contact infection and indirectly by fomites. They differ in the fact that *B. diphtheriæ* never causes a generalized invasion of the body, whereas the streptococcus that is responsible for scarlet fever is both a toxic and an invasive germ. Both germs are hardy and can survive for long periods outside the human body under suitable conditions. Both diseases are essentially diseases of childhood, especially of the school years from five to fifteen. These years are, indeed, a period of "running the gauntlet" of bacterial diseases for most children. A school can be a fertile agency for the spread of germs, and education is often interspersed with illness. It would be a wise policy to insist that every child before starting school should be tested for immunity to diphtheria and scarlet fever and that every susceptible child should be actively immunized. Coercion in the interests of individual and communal health is, however, at present generally held to be an intolerable interference with the freedom of the individual in a democracy. Many parents are ignorant of the value of immunization against these diseases; others are afraid of subjecting their children to any medical interference, and others are indifferent. The attitude of this last group appears to be that as long as their children are well, why worry about diseases they may never contract? After all, if they do contract diphtheria or scarlet fever, the chances are that they will recover under modern methods of treatment. The same people will nevertheless have their pet dog doctored for distemper and their tom-cat doctored to deprive it of its natural sexual faculties! The latter operation is performed chiefly in order to save them the bother of looking after the animal properly.

Voluntary artificial immunization is valuable, but it only covers a relatively small proportion of the population. Take small-pox vaccination as an example. The bulk of the present adult population of Great Britain is suspectible to that disease. Vaccination in infancy gives satisfactory protection only for some fifteen years, and all schoolchildren ought to be re-vaccinated before leaving school. Re-vaccination gives protection probably for life. Many infants escape vaccination under our

present voluntary system. Their parents argue that there is no need to subject them to this trouble when there has not been any outbreak of the disease in their neighbourhood within living memory. They are ignorant of the fact that modern means of transport, especially air-travel, make Britain far more vulnerable to the introduction of small-pox—and other infections—than it ever was in the past. We have to thank the unceasing vigilance of our Health Services that small-pox, cholera, and plague are kept out of these islands. They might be introduced, either accidentally or deliberately, and then those who oppose vaccination against small-pox would be the first to clamour for protective immunization.

The specific anti-serum treatment of diphtheria has been brilliantly successful in robbing a deadly disease of much of its terror, and is the only answer that need be made to those who call themselves anti-vivisectionists. The emphasis throughout the whole course of medical training is laid on the sanctity of life (animal as well as human) and the relief of suffering. There may be a rare sadist in the medical profession, but most medical laboratory workers regard the necessary experimental work that can only be performed on the lower animals as an honourable trust. There is far less cruelty to dumb animals in any of the bacteriological laboratories in these islands than is unwittingly inflicted upon pet animals by so-called animal lovers. One has only to think of the mental agonies inflicted upon pet animals who are deprived of, or prevented from fulfilling, their sex functions to appreciate this fact.

The specific anti-serum treatment of scarlet fever, though not as successful as that of diphtheria, has greatly reduced the mortality and disability rate of the disease. Scarlet fever is a much milder disease to-day than it was in our grandparents' time, but it still shows a distressing tendency to leave behind it painful and dangerous complications like mastoid disease, heart trouble, and kidney trouble. The mastoid trouble is caused by the streptococcus spreading from the throat, probably by way of the Eustachian tube, into the middle-ear—the part of the ear on the inner side of the ear-drum—and thence into the mastoid air cells. The heart and the kidney trouble both result from the damage done to those organs by the exo-toxin of the streptococcus after its absorption into the blood-stream. Prevention is always better than cure and, in view of the possibility of permanent damage to vital organs, it would seem that parents

are failing in their duty to their children if they refuse to allow them the benefit of protective immunization. Much is heard about the duties of children to their parents. The Bible contains numerous exhortations on that duty; but parents owe a greater duty to their children. The child does not choose either its birth or its parentage. To those who decide that choice belong the greater duties.

Whooping cough is another childhood infection and one that few children escape. The causal bacterium, *Bacillus pertussis*, is a very delicate pathogen and dies out rapidly outside the human body. The disease can therefore only be transmitted by direct contact or droplet infection, either from a carrier or an incubating case of the disease. Once the diagnosis has been established, the patient is quarantined, so that there is little risk of a patient spreading the infection, except through gross carelessness or faulty nursing. Contact-carriers are probably numerous in epidemic times, and are largely responsible for the spread of the disease. Partial protection of susceptible children therefore consists in keeping them from close association with other children until the epidemic has subsided. By close association is meant crowding together indoors, either at home or at the cinema. Playing together in the open-air is permissible, so long as direct contact does not occur. Although recovery from a natural attack of the disease usually confers a permanent immunity upon the individual, no satisfactory method of artificial immunization has yet been evolved. A vaccine of the germ given during the incubation period will sometimes prevent the disease from developing, and often makes the subsequent attack shorter and milder, but children cannot be artificially immunized against it as they can against diphtheria and scarlet fever. The characteristic paroxysmal cough is distressing both for the child and for the onlooker, and any treatment should be worth a trial that offers a chance of reducing the duration and violence of the cough. It is now generally agreed among bacteriologists that by the time the characteristic cough has become established the patient is no longer infectious; but woe betide the parents who take a " whooping " child into the company of other children! Most people recognize a " whoop " when they hear one, and that sound shares with the air-raid siren the power to arouse public alarm. Where there's sound there's fury is still the popular maxim about whooping cough.

Children quickly develop habits, as most parents know, and habit plays a part in the duration of the cough, which often drags on for six weeks or more. Medicines are of little avail to abolish the cough, though they may lessen its frequency and severity. In many cases the child will benefit by a change of surroundings for a week or two, because such a change does what drugs fail to do: it breaks the habit-association with the environment in which the disease was contracted.

Tuberculosis of the lungs (consumption) is now a diminishing disease in these islands, but it is still common enough to necessitate the upkeep of costly special hospitals (sanatoria) to deal exclusively with this and other forms of tuberculous disease of man. The causal agent, *Bacillus tuberculosis*, is widely spread throughout the nation, so much so that most of us have had a tuberculous infection and have recovered from it before we reach adult life. These infections are not clinically recognizable as tuberculous infections; they are atypical and sub-clinical, and we are blissfully unconscious of the successful resistance that our bodies have made. Throughout the past generations of our ancestors the tubercle bacillus has been quietly at work weeding out the weakly and the careless. Those individuals who resisted its attack have passed on a progressively increasing resistance to their descendants, and those of us who are free from tuberculous disease to-day owe our freedom in large measure to this inheritance. Man does not possess any natural immunity to *B. tuberculosis*, and it is a deadly germ among populations that have not adapted themselves to it. Among the South Pacific islanders, the negro tribes in Africa, and the Eskimos, tuberculosis has spread with devastating effect since its introduction by white explorers and colonists. We do not yet possess any certainly effective means of artificial immunization against the germ, although work that is now in progress is promising.

B. tuberculosis is a very hardy germ outside the human body and can remain alive and virulent for weeks, or even months, under suitable conditions. It is destroyed by direct sunlight, but it resists cold and drying indefinitely, and it is the most resistant of the non-sporing pathogenic germs to chemical disinfectants. It is especially resistant in the material that is coughed up from the lungs of a consumptive person, and this " sputum " is always a most dangerous vehicle for the dispersal of the germ. I have already illustrated this in a previous chapter, but I would emphasize here that it is the duty of every citizen to

obey, or enforce, the wise bye-laws against spitting in public vehicles that most Local Authorities enact. A consumptive person should carry a small bottle with a screw cap into which to spit. This bottle and its contents can be sterilized by heat, and its careful use insures the community against the deposition of the bacillus in places where it is liable to be brought into contact with susceptible persons. Consumption is not inherited, but a baby very quickly contracts the infection if it remains in contact with a tuberculous parent, or relative, or any other tuberculous person. Babies born to tuberculous parents can grow up into healthy individuals, if they are taken away from their homes shortly after birth and are reared in surroundings that are relatively free from the germ.

Rest, fresh air, good food, and sunlight are required by the human body to overcome *B. tuberculosis*. The reduction in the incidence of tuberculous disease in Great Britain is possibly as much the result of improved social and economic conditions as of inherited resistance. Our people are much better housed, clothed, and fed than they were a century ago and, while there is still much room for improvement, the progress that has been made has had an excellent effect upon the nation's health. No effective chemical or biological remedy has yet been discovered for tuberculosis, although each year sees the advertising of numerous alleged cures. The reader will do well to remember that the unaided human body is capable of curing itself of a tuberculous infection, and undoubtedly often succeeds. Any cure for the disease must therefore be tested on a large number of patients under carefully controlled conditions before it can be accepted. Many of the alleged cures are brought forward quite conscientiously by persons who sincerely believe in them, but who have not the necessary knowledge and experience, or the necessary facilities, to test their remedies properly. There are also a few unscrupulous individuals who are prepared wilfully to mislead the public in order to obtain money easily. Our existing laws offer these miscreants plenty of scope for their nefarious practices, but the public can protect itself against them by refusing to buy, or to use, any medicines that have not been sponsored by medical authority. If tuberculosis is discovered in its early stages, a majority of its victims can be cured by a combination of careful nursing, medical supervision, and individual co-operation. The last factor is all-important. Many patients relapse after their discharge from a sanatorium because

they will not continue the self-discipline and control that are essential for their complete recovery.

Tuberculosis is prevalent in cold, damp climates, especially in regions that are exposed during certain seasons of the year to cold, damp winds. It is almost unknown in warm, dry climates, such as are found in some desert regions and in some sheltered mountain valleys. Switzerland is noted for the treatment of consumption and other forms of tuberculosis, and it owes its curative powers to its pure, dry, bracing air on the slopes of its mountains, its strong sunlight, and the protection of many of its valleys from cold, damp winds. Occupation may also predispose to consumption. The inhalation of stone and metallic dusts is especially dangerous, and stonemasons, grinders, flint-knappers, and gold miners show an abnormally high incidence of infection. Any work, or mode of life, that subjects the human lungs to excessive strain, or to continuous irritation, predisposes the individual to attack by *B. tuberculosis*. Factory legislation in this country now endeavours to safeguard the worker in a dusty trade by insisting upon the extraction of the dust as far as is possible, upon a high standard of cleanliness of the premises, and upon frequent spraying, or washing, with water to lay the dust. No employer who claims to be humane can object to these provisions, especially as ill-health among his workers is detrimental to his interests. The refusal to take all reasonable precautions to safeguard the health of the worker is a false economy. Ill-health engenders dissatisfaction with the conditions of service, breeds antagonism between employee and employer, and costs far more in the long run than the maintenance of healthy conditions of labour.

B. tuberculosis is disseminated in a variety of ways—by droplet, direct contact, fomites, the inhalation of tuberculous dust, and the drinking of tuberculous milk. The germ that causes tuberculosis in cattle differs in certain respects from the human germ, but it is able to cause disease in man. Many of our herds of dairy cattle are infected, and the germ is excreted in the milk of tuberculous cows, which continue to yield milk until they are almost moribund. Efficient pasteurization, or home boiling, will kill the germ and make the milk safe for human consumption. The cattle type of *B. tuberculosis* is not dangerous for adults, but it is responsible for a large proportion of tuberculous disease in children under the age of 16, especially for tuberculous glands in the neck and for tuberculosis of the bones and joints. Tuber-

culosis could be eradicated from our milch-cattle if proper precautions were taken on a national scale, but these precautions are costly, and the farmers cannot be expected to shoulder the entire burden. Some day the nation will awake to the danger and expense of cattle tuberculosis and will demand energetic action on the part of the Government against a preventible disease. When that day comes, a national campaign, supported by the national purse, will eradicate the disease from our dairy-herds and will remove, at the same time, a huge volume of human suffering and disability. The reader of these remarks will possibly feel inclined to blame the Government for not taking the initiative. A people gets the Government it deserves, and it is no fault of the Government that the people are ignorant of, or indifferent to, problems that affect their individual health and happiness. When the nation makes up its mind that the time has come to abolish cattle tuberculosis, and is prepared to pay the price, it will find that the Government has all the necessary plans ready.

CHAPTER X

SOME INFECTIONS OF THE ALIMENTARY TRACT

From time to time a report appears in the Press that a number of people have been taken ill after eating oysters, or sausages, or some other food. The newspaper report is sometimes headed "Outbreak of Food Poisoning", but often it bears a more lurid and less accurate title. The words "food poisoning" cover a wide field, because they mean literally poisoning by food, or, more accurately, by substances eaten under the impression that they are foods. No sane man eats anything that is known to be poisonous if he can help it, and the term food therefore normally implies that the substance is safe for human consumption.

Some plants are naturally poisonous to man. The deadly nightshade of our hedgerows, with its clusters of attractive scarlet berries in the autumn, has tempted many a child, with serious results. The toadstool, *Amanita phalloides*, which may very closely resemble the common edible mushroom, is a deadly poison for which no antidote is known. Some plants are poisonous only in part. The leaves of rhubarb and potato are

poisonous to man, but the stalks of the one and the tubers of the other are wholesome and valuable foods. The flesh of some animals and fishes is poisonous at certain times, in most cases during the breeding season, but is safe for human consumption at other times. Some foods that are safe and nutritious for the majority of people may be poisonous for an unfortunate minority who have inherited or acquired a queer sensitivity to a particular food. The author knew a lady who became desperately ill after eating a strawberry, and he knows of several persons who dare not eat the smallest particle of egg, or of any food containing egg. These are cases of "allergy", about which something will be written in a later chapter.

To the bacteriologist the words "food poisoning" mean bacterial food poisoning, and this kind of poisoning results entirely from the activities of germs present in the food. There are two kinds of bacterial food poisoning—(*a*) the infective, and (*b*) the toxic. They can be distinguished by their manner of onset, by their clinical picture, and by their mortality rate. The toxic kind commences within a few hours of the eating of the contaminated food, as soon, in fact, as the bacterial toxin has been absorbed through the walls of the stomach and intestine into the circulation. The symptoms come on suddenly, often with explosive violence. The patient is seriously ill from the start, and recovery—when it occurs—is almost as sudden and dramatic as the onset. This kind of poisoning is caused by the presence of a bacterial toxin in the food before it was eaten. The infective kind is caused by the ingestion of living pathogenic germs present in the food. These require time to establish themselves in the body and make mischief, and therefore there is a time lag of two or more days—the incubation period—between the eating of the contaminated food and the onset of the disease. Moreover, the onset of the infective kind is often gradual and insidious; it rarely shows the explosive suddenness of the toxic kind.

The infective kind can be caused by several species of germs, but the ones most often implicated are non-sporing bacilli that are related on the one hand to *B. typhosus* and on the other to *B. coli*. They are known to bacteriologists as the Salmonella. There are many species of them, and the different species can only be separated and identified by delicate and lengthy laboratory tests. The Salmonellas are widely distributed in the bodies of human and animal carriers. Some of them are fairly hardy

germs that can survive for a considerable time outside the human and animal body. Many of them are pathogenic for the lower animals. They are all without exception excreted in the motions of the infected individual and are, in consequence, widely dispersed by flies and by vermin. They may also be dispersed sometimes by wind-blown fæcal dust. Man is always infected by eating contaminated food. The affected food is not always meat, although meat is the food that is most commonly implicated. Meat may be contaminated in one of two ways—(*a*) it may have come from a diseased animal that was infected prior to its slaughter, or (*b*) it may have become contaminated after the slaughter of the animal. The law says that no animal that is obviously diseased may be slaughtered for human consumption. If an animal cannot walk unaided into the slaughter-house on its own legs it is considered to be unfit for slaughter. This law can be evaded. The author saw some years ago an obviously ill bullock being driven in a van towards the public abattoir. The van stopped in a side street out of sight of the slaughter-house. The bullock was just able to stagger into the abattoir on its own legs and was promptly pole-axed as soon as it crossed the threshold. A few more minutes and it would have died on the premises from natural causes. Such instances of deliberate evasion of the law are rare; but there are a few unscrupulous persons who will do their best to evade the law rather than suffer the pecuniary loss entailed by the death of an animal which they have been rearing for the market. After slaughtering, meat may be contaminated in several ways—by the hands of a human carrier, either in the abattoir or in the butcher's shop, by flies, by vermin, and by wind-blown street dust. It may also be contaminated in the home by a carrier in the household.

Bacterial food poisoning is a comparatively rare disease in Great Britain for two reasons—(*a*) we cook most of our meat before eating it, and (*b*) we possess an efficient service of meat inspection. Every carcase, whether it is slaughtered in this country or imported from abroad, is inspected by highly trained men whose duty it is to see that no meat that is at all suspicious is sold to the public. It is only rarely that a piece of meat that is diseased escapes detection. There are several other dangerous human diseases that result from the ingestion of diseased meat, notably, hydatid disease and trichinosis. These two diseases are dangerous conditions caused by infestation of the human body by parasitic worms.

Thorough cooking destroys the Salmonellas, but, as I have previously emphasized, the meat must be properly cooked. Pork requires more cooking than beef and mutton. The cooking must be such that every part of the meat is held at an adequate temperature for a sufficient length of time. For practical purposes it is sufficient to ensure that no part of the meat remains red.

The meats that are chiefly responsible for outbreaks of the infective kind of bacterial food poisoning in this country are those that are partially cooked, or prepared, and are then eaten without any further cooking. Sausage-meat of all kinds, meat and pork pies and, less often, ham, tongue, pressed beef, and brawn. Oysters and other shellfish are also sometimes responsible. These are generally contaminated by human sewage washing over the beds. They are mechanical vectors of the germs, and not hosts, like our food animals. Among the latter, swine are more dangerous transmitters of bacterial food poisoning than cattle or sheep. Mutton is the safest meat; but its devotees are in a minority in a country whose national meat is roast beef.

Salmonella infections of man are fortunately relatively mild in most cases, and recovery is the rule. The mortality rate in most outbreaks is less than 2 per cent. of those attacked. The death rate is always higher among infants and invalids than among healthy adults, and it varies in different outbreaks. Man appears to acquire an increasing resistance to these germs with advancing age. The result of individual infection depends upon the dose of bacilli swallowed and upon the state of the stomach at that time. The larger the dose, the greater the risk of infection and the more severe the disease when it develops. The acid gastric juice kills the Salmonella if they are not protected against its action. If the stomach is full of food, however, the acid is used up in the digestive processes and the bacilli are able to slip through into the intestine in a protective casing of partly-digested, proteinaceous food. Individuals also vary considerably in their natural resistance to the Salmonellas, and the distribution of the germs in the contaminated food is often curiously uneven. The result is that if 100 people sit down to a dinner during which an equal amount of meat is eaten by each person, any number from 10 to 100 per cent. of those present may be attacked. As a rule, not more than 75 per cent. are attacked and all degrees of illness, from a transient attack of

diarrhœa to a serious illness lasting several weeks, are encountered. The distribution of the disease among the persons exposed to it is often most erratic, corresponding to the uneven distribution of the bacilli in the food. All the people at a particular table may be attacked and the rest of the company escape, or the victims may be gathered at random from the company.

The toxic kind of bacterial food poisoning is much rarer but more deadly than the infective kind. It results from the ingestion of the extremely powerful exotoxin of an anaërobic, spore-forming bacillus, *B. botulinus*. The resulting disease is known as botulism. The bacillus is an obligate saprophyte and is incapable of establishing itself within the living human and animal body. Its normal habitat is the soil and it is widely distributed over the earth, especially in virgin and uncultivated soils. It is quite by accident that it happens to secrete in the course of its biological activities a diffusible poison that is deadly for man in minute amounts. Botulinus toxin is the most powerful of the known bacterial toxins and is one of the most powerful poisons known to man. As the bacillis is an obligate anaërobe, it can only live and multiply in inanimate matter that is kept under strict anaërobic conditions. The modern methods of preserving foods by canning, potting, pickling, and smoking, provide the necessary anaërobic conditions. The foods that may be incriminated are therefore tinned meats and fish, potted meats and fish pastes, and smoked ham and other meats. The reader will appreciate that any food that is contained in a hermetically-sealed tin must be under anaërobic conditions, but the reason for the production of a similar state is a smoked ham is not so obvious. The process of smoking results in the coagulation of the proteins in the outermost layer of the meat, and this coagulated layer forms an air-tight seal around the meat. Tinned fruits are safe because *B. botulinus* cannot live in the syrup.

The usual sequence in an outbreak of botulism is as follows. A portion of meat that is to be canned is contaminated with earthy dust containing the spores of *B. botulinus*, either before it is placed in the tins, or after it is placed in the tins but before these are heated and sealed. The spores of the bacillus can withstand a high temperature for several hours, especially when they are buried deep in the meat. After the contaminated tins have been sealed and anaërobic conditions have been established

the spores are able to germinate. The vegetative cells then multiply and make the toxin, which diffuses slowly throughout the contents of the tin. The meat may, or may not, be appreciably altered in appearance, smell, or taste. In a majority of cases there is some appreciable alteration; but in a minority no alteration is detectable by the senses, and such tins are highly dangerous.

There is little danger of botulism if the caterer confines his or her purchases to the products of the well-known and old-established firms of canners and victuallers. The big and reputable firms are well aware of the danger of botulism and take strict and effective precautions to ensure against the contamination of their products by soil, dust, and dirt. Scrupulous cleanliness of employees and premises is their working-rule. Many of them achieve a standard of cleanliness that puts the clean housewife to shame, and they are always ready and anxious for the public to inspect their premises at any time. The danger of botulism arises when a one-man firm starts operations in a back-yard, or when the proprietor of the village store decides to embark upon the sale of potted meats and pastes made on the premises. Home canning and potting of meat, fish, and poultry may also be dangerous to the family if the housewife is not clean and careful. Home-made jam is safe, because the fruit acids and the high content of sugar inhibit the spores of the bacillus from germinating.

The death rate from botulism is always high in every outbreak, but it can be reduced by prompt treatment. A specific anti-serum is available that will neutralize the toxin and protect the individual, if it is given early enough. Botulinus toxin has an affinity for certain cells in the brain, and once it has reached those cells the anti-serum is of no avail. These cells control the vital functions of the body, and when they are destroyed by the toxin the individual dies. If the anti-serum is injected into the circulation before the toxin has reached the particular cells the individual will recover. The proper use of botulinus anti-serum is yet another instance of the value of prophylaxis as compared with therapy. It is not a case of prevention being better than cure in botulism; prevention is the only cure for the disease.

Fortunately it is a very rare disease in the British Isles. The last outbreak in these islands occurred in 1922 among a party of holiday-makers at Loch Maree in Ross-shire. Eight people

ate sandwiches made of potted wild-duck paste, prepared locally, and all died. The reader need not worry about botulism, however, as longs as he buys only the products of reputable firms.

A clear distinction must be made between food poisoning and the much commoner disturbance of the digestive functions that results from gluttony, gobbling, or an unsuitable diet. Nature provided man with teeth in order that he might chew his food thoroughly and mix it intimately with the digestive ferment in the saliva. Artificial dentures are a poor substitute for Nature's mill, and some people find a difficulty in chewing their food properly with them. Many people who are still in fortunate possession of their own teeth, however, bolt their food. The stomach was never intended as a receptacle for lumps of unchewed food and is apt to rebel against the imposition. A more frequent cause of digestive upset is the mixing of indigestible, or incompatible, foods. Some years ago a doctor in a northern town received an urgent call late at night to a miner's wife who was ill, so the informant said, with food poisoning. On arrival the doctor was told that the patient had been seized with violent pains in her " stomach " about two hours after her evening meal, and had since vomited. The patient and her family asserted that she had been poisoned by a tin of salmon, but her clinical condition did not suggest food poisoning. The doctor diagnosed her illness as a sharp attack of colic. He examined the tin of salmon, but could not find any appreciable alteration in what remained of the fish. However, he sent it to a laboratory for a bacteriological examination. A careful and tactful enquiry about the composition of the patient's meal confirmed the clinical diagnosis of colic, and the laboratory report on the salmon confirmed the absence of any evidence of bacterial food poisoning. The patient had sat down with her next-door neighbour—who also contracted an attack of colic—to a high tea consisting of steak and onions, tinned salmon, bread and dripping, lardy cake, beer, and tea. The tea apparently was an after-thought after the supply of beer gave out. Only a cast-iron inside would be likely to accept that mixture without some protest!

The above example is probably an extreme one, but some people at times eat too much, and others mix their foods unwisely. No great harm is done as a rule, providing that the sufferers do not lodge unwarranted complaints of food poison-

ing with the Local Health Authority. The average Medical Officer of Health has his time fully occupied in dealing with true outbreaks and sporadic cases of bacterial disease, and silly complaints by ignorant people make his work much more difficult. An American investigation, some years ago, revealed that 80 per cent. of alleged cases of food poisoning reported to the Public Health Authorities were nothing more than digestive upsets due to greed, folly, or ignorance. It is as unwise to mix some foods as it is to mix drinks, and it is always unwise to eat simply for the sake of eating.

Typhoid fever has been one of the great scourges of mankind and is still prevalent in epidemic form in the East. It is especially a disease of armies and of populations exposed to the devastation of war and weakened by its aftermath of suffering and famine. Before the introduction of artificial immunization of the individual by vaccine, it was responsible for more death and disablement in many campaigns than all other causes combined. During the Boer War, the British Army in South Africa had over 57,000 cases of typhoid fever, with over 8,000 deaths, among some 550,000 troops, whereas only 7,500 odd died of wounds received in battle. During the European War of 1914–18, thanks to the efficacy of prophylactic vaccination, the incidence of typhoid fever among some $5\frac{1}{2}$ million British troops was negligible in all theatres of the war.

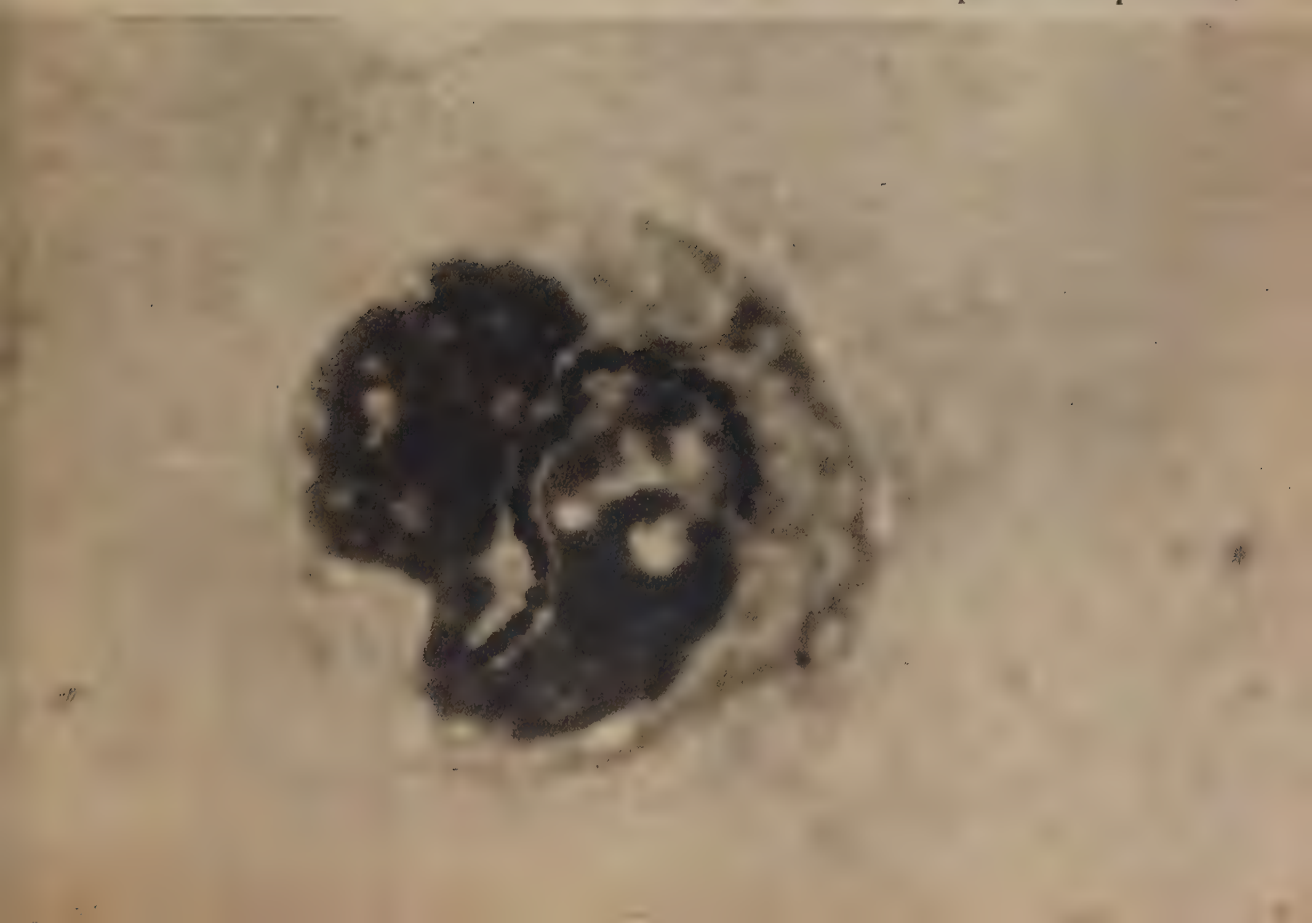
It is essentially a water-borne disease, although it can be spread by milk and other foods, and it is more prevalent in temperate than in tropical climates. It has, however, a world-wide distribution and shows everywhere a maximum seasonal incidence in the autumn months. It is especially a disease of youth and early adult life, with a maximum incidence between the ages of 15 and 25, but no age and neither sex is exempt. Man has no natural immunity against it, but individuals show variable degrees of natural resistance and not all who are exposed to infection contract the disease. Recovery from an attack generally confers a life-long immunity upon the individual. It is a specific human disease and is unknown, either naturally or experimentally, among the lower animals.

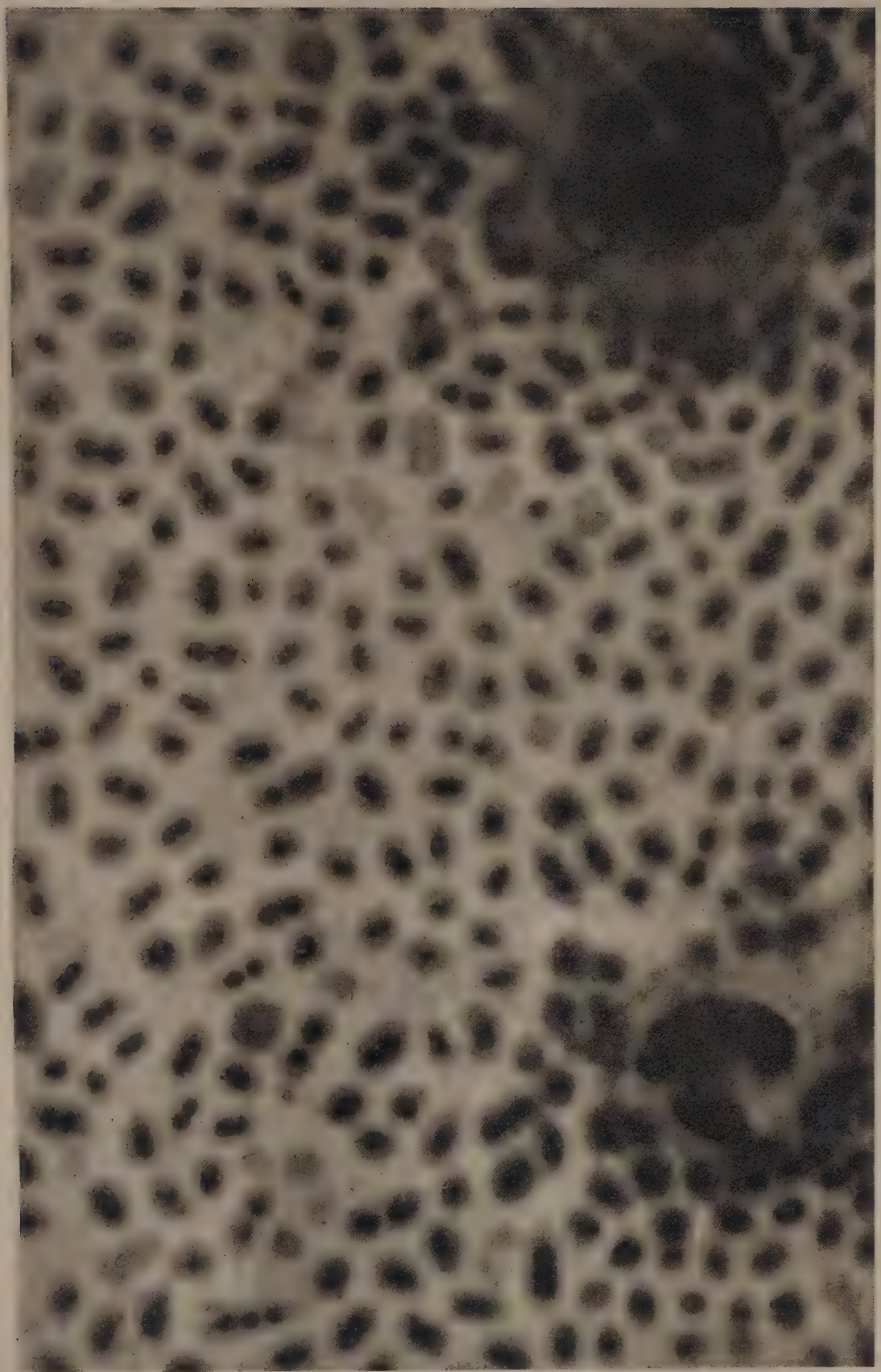
The causal germ, *Bacillus typhosus*, is a motile, non-sporing, aërobic bacillus. It is an obligate parasite of man, incapable of a free-living existence outside the human body, and is never found in nature except in the immediate or recent presence of a typhoid fever patient, or carrier. It is, however, fairly resistant

1. *B. Typhosus stained to show its Flagella.*

The slender filaments of protoplasm are emerging from all round the periphery of the short, plump, cylindrical cell. Two detached flagella, and three other bacillary cells devoid of flagella, are also seen in the photograph. The mottled background is an artefact.

2. The photograph shows a microphage that has succeeded in ingesting a chain of streptococci. This is the first stage of phagocytosis. The cell then digests the bacterium to complete the process.



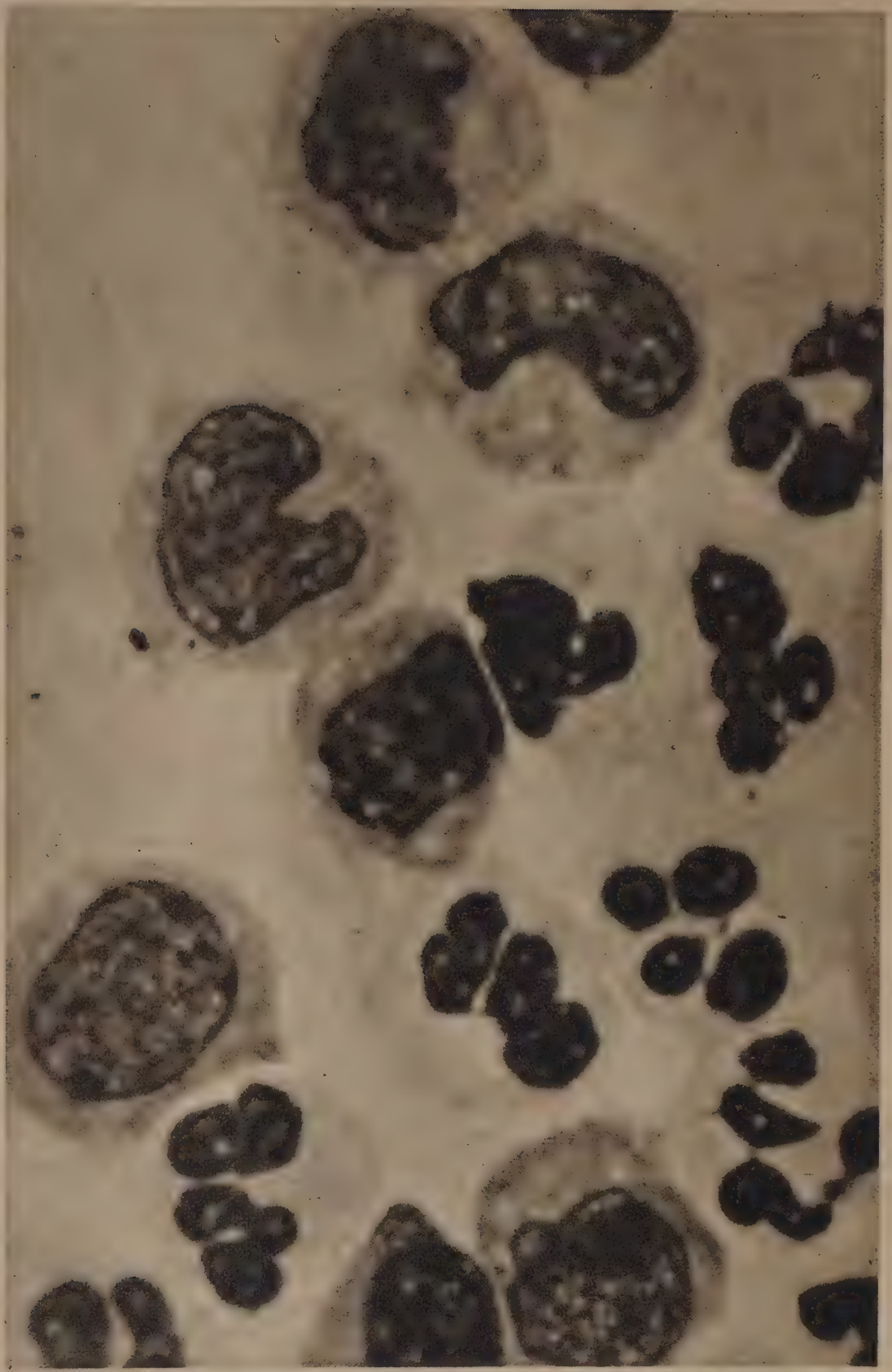


3. *Pneumococcus, in a Film of purulent Cerebro-spinal Fluid, stained to show its Capsule.*

The coccus is the central darker-stained oval, or ovoid, body. Some of the cocci are single, but several typical diplococcal forms are present and a single capsule surrounds these. A few " ghost " capsules are present also. These are empty capsules, left behind after the death and dissolution of the germ that made them. The two large, darkly-stained bodies are leucocytes.

4. *Culture of a Spore-Forming, Aerobic Bacillus, stained to show the Spores.*

The oval, black bodies, lying inside the grey, cylindrical cells, are the spores. Four of the spores have failed to stain properly and only their thick envelopes have partially retained the stain.



5. *Film of Pus from a healing Gonococcal Conjunctivitis in an Infant.*

This photograph shows the two kinds of wandering phagocyte that are chiefly concerned in the human body's defence against bacterial attack. The smaller cells, with the faint grey outlines and the black, multi-lobed nuclei, are polymorphonuclear leucocytes, or microphages. The larger cells, with the dark-grey outlines and the relatively large, ovoid, polyhedral, or indented nuclei, are mononuclear leucocytes, or macrophages.

6. This photograph shows a microscopic section of human skin. The section has been cut longitudinally through a hair follicle. The dense, black band at the top is the external horny layer. Inside the follicle numerous black streaks can be seen running longitudinally. These are solid columns of staphylococci. The two black spots lower down are colonies of the germ in the base of the follicle. The irregular objects, looking something like clusters of tiny frog-spawn, are some of the glands of the skin.

This photograph illustrates the early phase of the formation of a boil.

7. Chains of Streptococci in a Film of Pus from an Abscess.

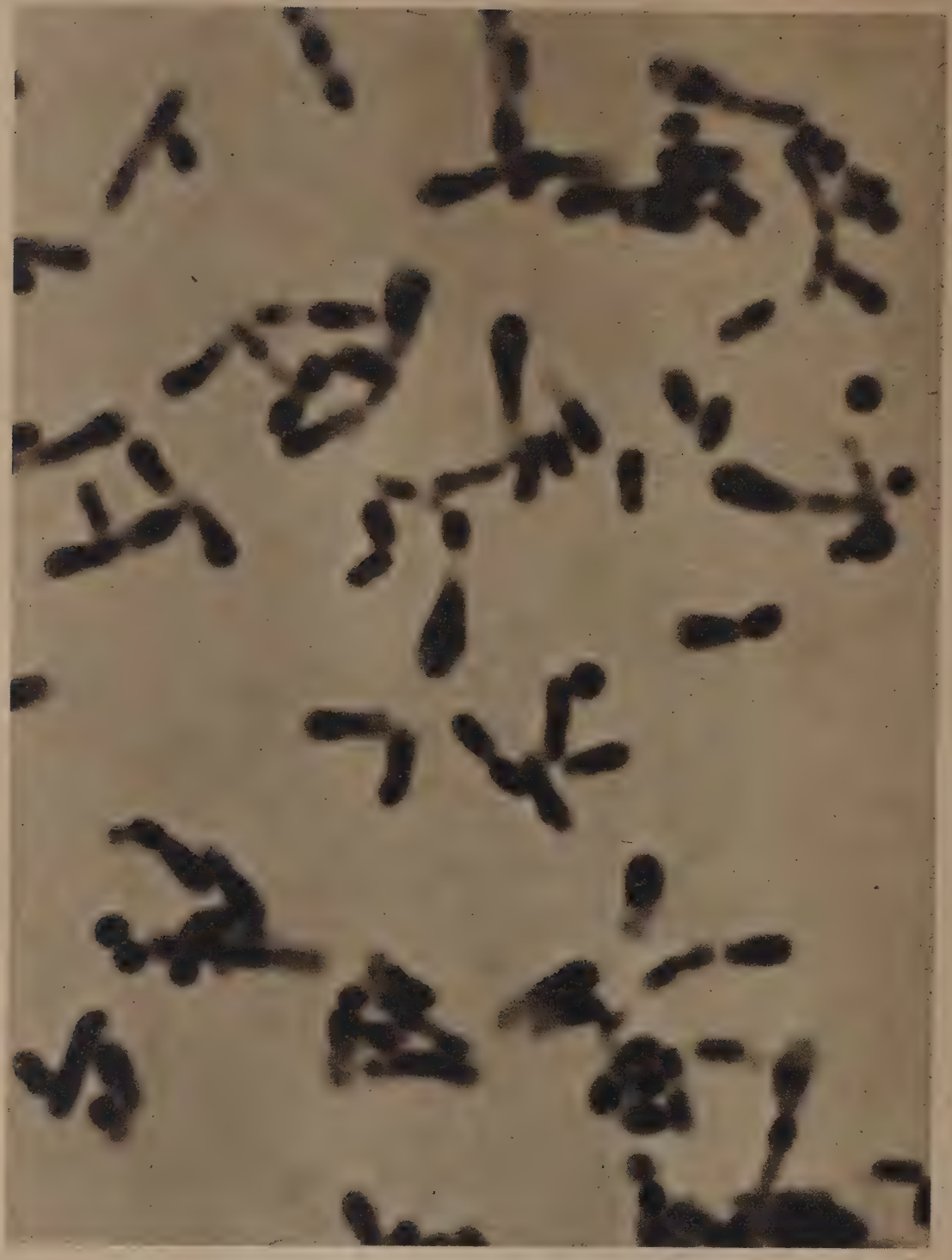
The large dark objects are leucocytes. A similar streptococcus is the causal agent of puerperal fever, scarlet fever, erysipelas, acute tonsillitis, and the bulk of cases of mastoid disease.

8. *Pneumococci in a Film of the Author's purulent Nasal Discharge, at the Height of a bad Cold.*

One of the leucocytes has phagocytosed several germs, and another has rounded up a single, forlorn coccus. The author made an uneventful recovery from this cold because his phagocytes were active, and because he refrained from poisoning them by pouring into his body any patent " cold " or " catarrh " *cures.*

9. *A Pure Culture of B. Diphtheriae.*

The causal agent of diphtheriae can often be identified under the microscope by the presence of certain large granules within the bacillary cell. These granules, which are composed of a substance known as metachromatin, are characteristically bi-polar in their distribution, *i.e.*, one granule at each end of the rod. When the bacillus is stained in a particular way, the granules stain a deep blue-black colour, while the body of the bacillus is stained a light brown. The contrast in colour enables the bacteriologist to pick out the diphtheria bacillus under the microscope from among a mixture of other bacteria. This photograph is unfortunately slightly out of focus, but it is sufficiently clear for the bi-polar situation of the granules to be seen.



10. *A Pure Culture of B. Diphtheriae.*

A comparison of this photograph with the previous plate will give the reader some idea of what is meant by bacterial pleomorphism—i.e., the ability that most bacteria possess to alter their size and shape in varying degree within the limits of their basic form. This is the same germ as that in 9, but it has been cultivated on a different foodstuff.

It is the inherent capacity for pleomorphism among the bacteria that makes the bacteriologist's task at once so difficult and so interesting. His work is that of a detective in Lilliput. Many people, including quite a number of doctors—who should know better—seem to think that the bacteriologist has only to look down a microscope to identify a bacterium. These two plates will, I hope, convince the reader that the bacteriologist's task is not always quite so simple.

outside the human body and can survive for as long as five months under certain conditions. It is rapidly killed by sunlight, but is resistant to cold and survives for several months in fæcal matter that is kept frozen. It can remain alive in sewage sludge up to five weeks. It can remain alive and virulent in fresh water for one week under ordinary climatic conditions in this country. It remains alive in ice for several weeks; in oyster fluid up to three weeks, and in oysters kept in their shells at 45° F. up to two months. In general, its survival outside the human body is determined largely by the temperature of its environment—the lower the temperature, the longer the survival time.

The bacillus can only cause typhoid fever by entering the human body through the alimentary tract, and the disease therefore always results from the ingestion of water, milk, ice-cream, and food contaminated with the germ. The source of this contamination may be the fæces (and urine) of a patient, or a carrier, or the fingers of a carrier. Transit from fæces to water, milk, and food may be effected through the agency of flies, vermin, rain, or wind; but flies are easily the commonest agent.

The bacillus cannot pass the normal acid barrier of the stomach, and infection of the individual therefore depends upon the state of the gastric secretion at the time the germ is introduced into the stomach. Between meals the stomach normally contains a quantity of secretion, known as the resting juice, that has no acid content. If the bacillus is introduced into the stomach in a drink of water, or milk, between meals, it will therefore escape the germicidal action of the gastric acid and will pass through unharmed into the small intestine. If the stomach is full of food when the bacillus is introduced, the acid secretion may not be able to get at the germ, or the bacillus may be protected by a covering of coagulated proteins, or the acid may be neutralized by the nature of the food. On the other hand, hydrochloric acid is secreted into the stomach continuously during a meal, and in many cases the bacillus is destroyed by it. In general, therefore, the swallowing of *B. typhosus* between meals will usually result in infection, whereas its ingestion during a meal provides the individual with a good chance of escape. This barrier action of the gastric secretion explains why some persons who are exposed to infection escape the disease.

When *B. typhosus* reaches the bowel, it quickly makes its way through the walls of the gut, enters the blood-stream, and

is carried to the spleen and gall-bladder, in which organs it multiplies rapidly for several days. By the end of a week it has returned to the tissues of the bowel, in which it continues its multiplication. It is excreted in enormous numbers in the patient's motions, and sometimes also in the urine, from the end of the first to the end of the third or fourth week from the onset of illness. Often the patient's motions are of a fluid, or semi-fluid, consistency and the bowel action is abnormally frequent. Sometimes, however, the patient suffers from obstinate constipation instead of diarrhœa. Convalescence begins in a mild, uncomplicated case about the end of the fourth week and is complete about the end of the seventh week. The activities of the germ result in the formation of numerous ulcers in the walls of the small bowel, and the danger of typhoid fever is that either one or more of these ulcers may rupture into the abdominal cavity to cause a fatal peritonitis, or a large blood-vessel may be eroded and a fatal hæmorrhage result. Severe bleeding often does occur during the active stages of the disease, owing to the erosion of small blood-vessels involved in the ulcers.

The mortality rate varies in different epidemics, but generally it does not exceed 20 per cent. of the clinically recognizable cases of the disease. All degrees of infection may be encountered, from a transient attack of diarrhœa, or a few days of vague ill-health, to a fulminating septicæmia that is rapidly fatal. No specific remedy for the disease is yet available, but most cases recover with careful nursing and expert control of the diet. Scrupulous care and strict attention must be given to the immediate sterilization by heat or chemicals of the urine, motions, and any other discharges from the patient's body. No one, other than the nurse and the doctor, should be allowed access to the patient. Flies must be prevented from entering the sick-room by effective screening. No bed-linen, clothing, furniture, carpets, curtains, books, food or toilet utensils must be allowed to leave the sick-room until they have been thoroughly disinfected, or have been packed in air-tight and dust-proof receptacles ready for sterilization.

The risk of typhoid fever in Great Britain during peace-time is not sufficient to alarm any one. A number of sporadic cases are reported annually, and at long intervals an epidemic breaks out. Such outbreaks are, however, quickly localized and brought under control by the national Health Services. The individual can contribute to his own and the communal safety by exercising

reasonable care about the deposition of fæcal and urinary matter and about the assuaging of his thirst in summer weather. The water supplies of our cities and towns are kept under constant, expert supervision, and it is only rarely that any danger need be apprehended from drinking such supplies. In rural districts, and especially in remote country districts, however, the position is not so satisfactory. In a densely populated country like England no stream, brook, spring, lake, or pond is permanently safe against contamination with *B. typhosus*. Many of the shallow wells that serve as public supplies in country districts are also open to pollution. It is therefore a wise policy not to drink the water of any unknown surface supply during the summer months, unless one is "dying of thirst", and such a state is not like to arise often in a thickly-populated and civilized country. An additional safeguard is to ensure that all food that is eaten uncooked is protected from contamination by flies.

Septic infections of the alimentary tract are uncommon, if we except tonsillitis, dental decay, and pyorrhœa, all of which are confined to the mouth. The tonsils are roughly globular masses of lymphoid tissue that nestle in recesses at the back of the mouth, one gland on either side of the cavity. They probably function as poison filters, and their situation is such that they must often be exposed to bacterial attack. The commonest pathogenic germ that attacks them is a streptococcus, the same germ that is responsible for scarlet fever and childbirth fever. The only difference between acute tonsillitis and scarlet fever is, in fact, that in the latter condition the patient shows a generalized scarlet rash in addition to the tonsillar inflammation. I shall refer to this phenomenon in the discussion on allergy. Tonsillitis may have serious consequences and it is not a disease that one can afford to ignore. It is principally a disease of childhood and youth, although no age is exempt. Repeated attacks lead to structural changes in the tonsils and the establishment of chronic septic foci, from which there is a continuous absorption of toxin that steadily undermines the individual's general health. There is only one treatment for the chronic, septic tonsil—surgical removal by dissection, not by the guillotine. The tonsillar guillotine has now fortunately fallen into disfavour, because it only slices off the protruding portion of the gland, leaving behind a stump of tonsillar tissue that may be more dangerous than the whole gland. The tonsil can only be removed in its entirety by dissecting it away from the sur-

rounding tissues. It is not a difficult operation in the child and most children recover from it with surprising rapidity. Tonsillectomy has become fashionable in recent years and there is evidence that the operation is sometimes performed without much justification. Simple enlargement of the gland in a child is not a sufficient reason for its removal. The child's tonsil swells up on the slightest provocation, but it subsides as rapidly when the oral trouble has been overcome. A temporary enlargement is the manifestation of the gland's defensive reaction, and it is only when this enlargement persists and the gland becomes hard, with gaping crypts from which pus oozes, that its removal is necessary. If tonsillectomy is necessary, it is a wise policy to have both glands removed at the one operation, because usually both are involved in the septic state, although the degree of involvement is often unequal. Parents who are doubtful, or fearful, about the removal of their child's tonsils should not hesitate to seek a second medical opinion. Neither the school, nor the family, doctor is infallible, and two heads are always better than one. If the two opinions agree that tonsillectomy is indicated, the parents will be doing their child a grave disservice if they do not give their consent to the operation. Chronic tonsillar sepsis may result in irreparable damage to the heart, or the kidneys, or to crippling disablement of the tendons and joints. If the two opinions are diametrically opposed—a not uncommon situation in medical matters—a third and final opinion should be sought.

Tonsillar infections are spread chiefly by direct contact and droplet infection. Many people carry the streptococcus for variable periods in their mouth as a commensal. As long as they keep in good general health the germ causes no trouble; but if they become run down by overwork and worry, or their general health is reduced by some internal disease, or their local resistance is lowered by any means, the streptococcus at once starts to multiply in the crypts of the tonsils and diffuse its toxin. It is this toxin that is responsible for the after-effects of tonsillitis.

Very few persons live a normal span of life without suffering from tooth-ache. The pain is a warning signal that there is something definitely wrong with one or more of the individual's teeth. Each tooth is supplied with a small nerve and a tiny artery and vein that run down into it from the jaw bone in a little canal in the tooth, the pulp canal. The nerve and blood

supply keep the tissue of the tooth alive. The pulp canal is surrounded by dentine, the comparatively soft tissue that comprises the bulk of the tooth. Externally, the dentine is surrounded and protected by a thin layer of hard, resistant enamel. As far as we know at present, no bacteria are able to penetrate the intact enamel—it is an even more resistant tissue than the skin. If any breaches occur in the enamel, however, the bacteria that are normally present in the mouth are able to attack the soft dentine underneath. Such breaches may be made by acid action, resulting from the local accumulation of acids formed by the decomposition of food debris. The acids dissolve the enamel. It may also be breached by injury, due to biting hard sweets and other hard material. A diet that is deficient in certain vitamins may result in the formation of an incomplete, or faulty, enamel covering, or to the impairment of an enamel layer that was previously effective. The strength and completeness of the enamel layer vary naturally in different individuals; some persons have "soft" teeth that decay easily because the layer is defective, others have "hard" teeth and scarcely know what dental decay means. Once the mouth bacteria have reached the dentine they rapidly produce areas of liquefaction in it, and the coalescence of these results in the formation of a cavity in the tooth. The cavity quickly becomes filled with bacteria and food debris and forms a most efficient culture tube. Bacterial activity in the cavity ensures a continuation of the process of cavitation until the pulp canal is reached. Then the dental nerve reacts to the irritation of the bacterial enzymes and poisons and the sufferer usually hurriedly repairs to the dentist.

The best protection against dental decay and its concomitant pain is provided by careful dental hygiene, a sensible diet, and regular visits to the dentist at six-monthly intervals, or less. If a stitch in time really does save nine, a cavity taken in time certainly means the saving of a tooth. Brushing the teeth daily, especially just before bed-time, removes the particles of food that otherwise cling around the teeth and prevents the local formation of acid. Plain water and a soft, clean tooth-brush are all that are required. The numerous dentifrices that are marketed have no germicidal value as they are used in practice; but they possibly give a feeling of safety, they are refreshing, and their detergent properties keep the teeth white and clean-looking. Alkaline pastes and powders are probably more useful

than acid ones, and smooth pastes are safer than gritty powders, because the grit may cause abrasions of the enamel.

If the nerve to the tooth is destroyed, either by bacterial action or, artificially, by heat or chemicals, the tooth is devitalized—*i.e.*, it is converted into dead tissue. Dead tissue is always dangerous, wherever it may be located in the human body, because it attracts germs and provides them with a suitable portal of entry to the tissues. The defensive mechanisms of the body cannot operate in dead tissue, and the germs may gain so great a start that when they eventually emerge from their retreat the body's defences cannot cope with them.

It was the fashion some years ago among dental surgeons to devitalize a badly decayed tooth, fill the cavity with cement, and then crown the tooth with a gold cap. This treatment was based upon the fallacy that a dead natural tooth must be better than an artificial one. If, however, a tooth is so badly decayed that the pulp canal is involved, there is only one safe and effective treatment—extraction. It is almost impossible for the most skilful dentist to fill the pulp canal of a tooth with a sterile filling. In most cases a colony of germs is left at the apex of the tooth after the pulp canal is filled, and from this focus there may be a steady, insidious absorption of bacterial toxins, sometimes with unfortunate effects on the individual. As a school-boy, I had six of my teeth root-filled and gold-crowned. Twelve years afterwards I began to suffer with arthritic trouble in my wrist and knee-joints which threatened to cripple me and prevent me from continuing with my professional work. Suspecting where the mischief lay, I asked a colleague to *X*-ray my dead teeth. The radiographs showed clearly that every one of my root-filled teeth was infected at the apex. Since their extraction I have not experienced any more joint trouble.

The reader must not jump to the conclusion from my experience that all arthritis (inflammation of a joint) is the result of the root-filling of teeth. Many people suffer from arthritis who have never had a tooth root-filled, and the crippling and distressing disease known as rheumatoid arthritis, which is all too common in middle age, does not appear to be related in an way to dental trouble, or interference. People who have had teeth root-filled and crowned would, however, be well advised to have those teeth *X*-rayed if, at any time, they develop arthritic trouble, or any vague illness for which their doctor can find no obvious cause.

CHAPTER XI

SOME INFECTIONS OF THE URINARY TRACT

BACTERIA can attack any part of the human urinary tract, but the bladder is the part that is most often invaded. Inflammation of the bladder, cystitis (pronounced sist-eye-tiss), can be caused by several different species of pathogenic germs. The commonest agent is *Bacillus coli*, the bacterium that is normally present in the healthy human bowel, and the next commonest is *B. proteus*. This is an aërobic, motile germ that is found widely distributed in any putrefying matter and in sewage. It is frequently present in small numbers as a commensal in the human bowel. It is one of the most active of the bacteria that initiate putrefaction, and is primarily a saprophyte that is capable of developing a mild pathogenicity for man under certain conditions.

B. coli cystitis can occur at any age in either sex, but it is much commoner in the female than in the male at all ages, and it is commoner in adults than in children. The reasons for the well-marked sex incidence are not certainly known, although some authorities believe that the anatomical arrangement of the female organs is the determining factor. The bladder appears to be invaded by way of the blood-stream in most cases. The bacillus somehow enters the blood-stream, probably through the rich network of veins in the walls of the bowel, and is then localized in the wall of the bladder. The transient septicæmia does not cause much disturbance of the general health as a rule, and the bacillus is able to pass through the bowel wall in the absence of any appreciable damage to that tissue. When it reaches the bladder, it sets up an acute inflammatory reaction that is accompanied by pus formation and a variable degree of destruction of the surface layer of the bladder. The necrotic tissue sloughs away and, together with the pus, is washed out in the urine.

Cystitis is not dangerous to life, but it is a depressing disease that lowers the mental and bodily health of the individual and so predisposes to other diseases. If it is neglected it may lead to structural alterations in the wall of the bladder that impair the efficiency of that organ. The kidneys are sensitive to any obstruction to their free secretion of urine, and if the function of the bladder is impaired a severe strain may be thrown upon

the kidneys. The chief danger of long-continued cystitis is that of remote interference with the function of the kidneys. Fortunately cystitis is a curable disease, and most cases can be rapidly cured by medical treatment if they are taken in time. If the condition has passed into the chronic state before medical help is sought, the outlook is not so satisfactory, because chronic cystitis is much more refractory to treatment than the acute form. *B. coli* possesses the power to adapt itself to changing environmental conditions, and once it has acclimatized itself to a parasitic existence in the wall of the bladder it is a very difficult germ to eradicate.

The bladder may be infected from extraneous sources occasionally, and the invading germ is then often a streptococcus, or a staphylococcus. It may also be involved in a septicæmia, such as occurs in typhoid fever. It is commonly involved in any bacterial infection of the kidneys, because the germs are washed down into it in the urine. Tuberculosis of the bladder is invariably secondary to renal disease. On the whole, however, the bladder possesses a relatively high natural resistance to bacterial attack.

B. coli is also the germ that is most often responsible for infections of the kidneys. The kidney is one of the vital organs of the body, and complete failure of its function is incompatible with life. It is a complex filter, whose function is to extract the poisonous waste products of our metabolism from our blood and eject them from our body in the urine. Three distinct structures combine to form the filtering mechanism and the substance of the kidney—(*a*) the glomeruli, which filter water and salts out of the blood; (*b*) a complicated system of tubules, in which selective filtration and absorption take place, and (*c*) a reservoir, the pelvis of the kidney, where the urine collects before it is expelled down the ureter into the bladder. By reason of its structure and blood supply, the kidney is susceptible to bacterial invasion by either of two routes, (*a*) by way of the blood-stream, or (*b*) by way of the blood-vessels and lymphatics that run alongside the ureter. The first route is known as the hæmatogenous path, the second as the ascending path, of infection. Fig. 1 may help the reader to follow the text.

The parenchyma of the kidney contains the vitally important filtering mechanisms, and any gross destruction of its tissue results in the failure of the renal function. It is a less resistant tissue than the pelvis, which can be invaded by germs without

any serious interference with the filtering power of the kidney. A hæmatogenous infection produces the condition known as pyelonephritis, an ascending infection produces the renal disease known as pyelitis. The latter is the commoner and less dangerous of the two forms. It may also, however, result from a

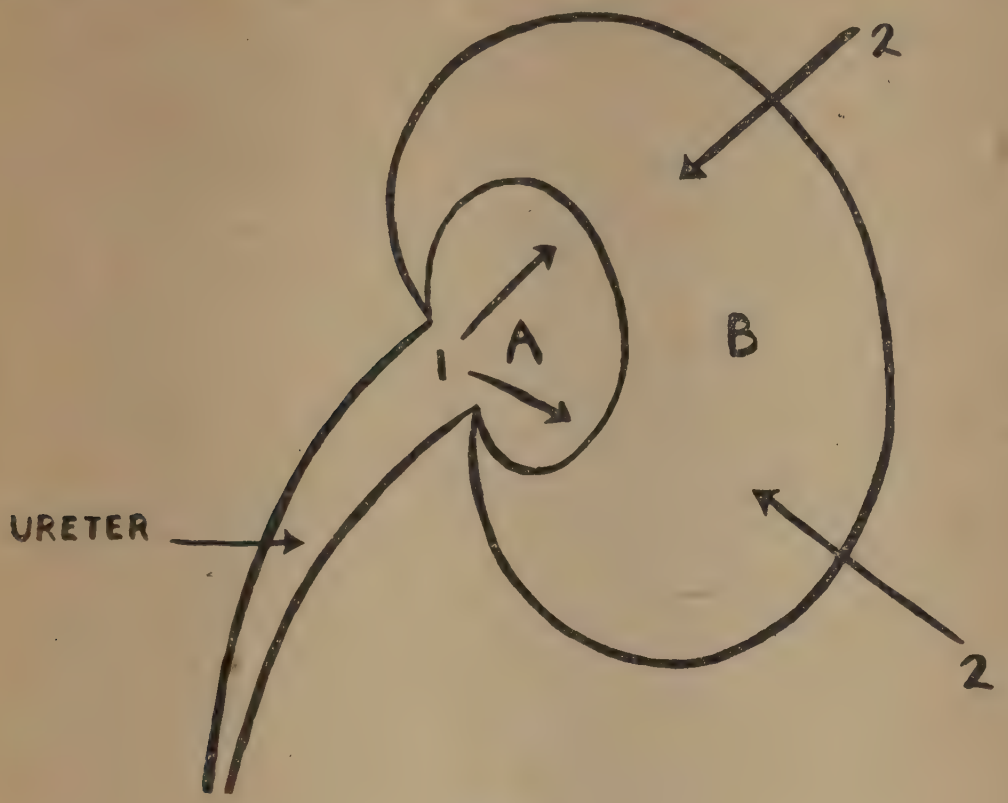


FIG. 1.

A.—Pelvis of kidney.

B.—Parenchyma (pronounced parren-keye-mar) of kidney containing the glomeruli and the tubules.

1.—The arrows show the direction taken by an ascending (ureteric) infection, which tends to travel from the pelvis outwards towards the periphery.

2.—The arrows show the direction taken by a hæmatogenous infection, which tends to travel from the periphery inwards towards the pelvis.

blood-stream invasion, because the parenchyma and the pelvis of the kidney have a separate blood supply.

Pyelitis may be secondary to a cystitis, or it may develop as a primary infection in the absence of any infection elsewhere in the urinary tract. It is much commoner in women than in men and is probably the commonest infection of the urinary tract met with in children. Both kidneys may be attacked simultaneously, but in a majority of cases the disease is at first confined to the

one kidney, and if prompt treatment is given, the other kidney often escapes. There is a form of pyelitis that is peculiarly associated with pregnancy. It is a mild form that usually does not cause serious disturbance of the woman's general health and does not harm the unborn child, or make its birth more difficult. Often it subsides spontaneously after the child is born. The fact that it is generally a mild and self-limiting disease does not mean, however, that it can be ignored with impunity. The patient requires medical treatment and supervision, and the sooner she places herself under treatment, the quicker and more complete will be her recovery. Within the past few years several valuable new remedies for the treatment of pyelitis have been discovered, and most cases can now be cured if they are taken in time. If the infection is confined to the one kidney, and to the pelvis of that kidney, no permanent damage is done to the renal function. One kidney is able to do all the work required to keep the body healthy, and people who have been obliged to have one of their kidneys removed by the surgeon live active and normal lives. Bilateral pyelitis is, of course, more dangerous because of the greater risk of permanent damage to the renal function, but the outlook is good in most cases. Much depends upon early diagnosis and treatment of the disease. As with cystitis, and for much the same reason, chronic pyelitis is more difficult to cure than the acute form.

Although their situation within the abdominal cavity affords the kidneys a good degree of protection, they may be injured by sudden pressure applied in the small of the back, and they are sensitive to local chilling and to internal strains. It is probable that a slight injury to the kidney often determines bacterial localization in the organ. There is evidence that bacteria often enter the blood-stream in small numbers without causing any recognizable disturbance of the individual's health. Under ordinary conditions the blood is able to deal effectively with these germs, but if there is an area of damaged tissue in the body it attracts them and provides them with a suitable site for colonization. Local chilling of the kidneys may occur after strenuous physical exertion, or after any muscular activity in hot weather. If an individual perspires freely from the trunk and then sits about in his sweat-soaked clothing, some degree of chilling of the trunk is bound to occur. It is a wise precaution to change into dry clothing as soon as possible after any exertion that has caused profuse perspiration. If a bath cannot be taken, a brisk

rub down with a coarse towel safeguards against chill and acts as a tonic to the skin. Severe strain may be thrown on the kidney by excessive distension of the bladder. The bladder is an elastic organ that is designed for expansion, but there is a limit to the degree of distension that it can support without injury to the individual. Some of our modern conventions are foolish when regarded from a medical standpoint. Many men will sit in discomfort with a full bladder for hours at a concert, or in a cinema, or even in the house of a friend, rather than let it be known that they have a bladder that urgently needs to be emptied. Children will go for long periods with a full bladder rather than interrupt their play. When the sales are in full swing, or a day's shopping in town is in progress, women will risk over-distension of the bladder in order to secure a bargain. When the bladder has reached its normal limit of distension, the flow of urine from the kidneys is dammed back and an increasing back-pressure operates to interfere with the function of the kidneys. The mark of a considerate host is that he, or she, is careful to ensure that no guest is obliged to endure a period of discomfort, and possible injury, in order to conform to a foolish convention.

A pyelonephritis may be an incident in, or a sequel to, a septicæmia caused by any pathogenic germ. As the kidney is the filter for the human body, it acts as a trap for any bacteria that may be circulating in the blood-stream. Toxins that are circulating in the blood will also be brought to it, and toxic nephritis is a common concomitant of diphtheria and scarlet fever. In spite, however, of its susceptibility to attack by germs and their toxins, fatal infections of the kidney are relatively rare. It has a rich blood supply, and this ensures the rapid mobilization of the defensive mechanisms of the body in the organ, and the natural resistance of the renal tissue is higher than that of some of the other internal organs of the body. None of the common pathogenic germs shows any predilection for the kidney, but one of the pathogenic spirochætes chooses that organ and the liver as its principal sites of attack. This germ, *Leptospira icterohæmorrhagica*, is the causal agent of a rare disease known as Infective Jaundice. Its natural host is the rat. It is excreted in large numbers in the urine of an infected animal and, as the rat has no sanitary instincts, it is spread wherever the rat goes. It is able to survive for long periods in water, mud, and slime, and man is infected by contact with these substances. In Great

Britain the disease is chiefly restricted to certain occupations—miners, sewer-men—in the pursuit of which men are brought into contact with moist matter contaminated with the spirochæte by the rat. Occasionally, the disease may be contracted by a person bathing in a canal, or a pond. The spirochæte is able to penetrate the human skin, especially when the skin has been softened by contact with water, and it can also enter the body through the alimentary canal. Infective jaundice is a dangerous disease, but there is very little risk for the ordinary individual.

CHAPTER XII

SOME INFECTIONS OF THE GENITAL TRACT

THE sex instinct is one of the strongest, and can be one of the most ennobling, of human instincts. It is one of the major tragedies of humanity that its abuse exposes man to some of the worst microbial diseases to which he is subject. Most of the serious infections of the human genital tract are contracted by direct contact during sexual intercourse. The bacterial diseases that are principally transmitted in this manner are known as the Venereal Diseases and two of them, syphilis (or pox) and gonorrhœa (or clap), are unfortunately all too common in the British Isles to-day. Annually they claim thousands of victims, many through ignorance, some through curiosity, some through betrayed trust, and a few through inherent vice.

Gonorrhœa is one of the oldest of the bacterial diseases of man, almost as old probably as the human race itself. References are made to it in many ancient writings, and the Book of Leviticus is largely concerned with advice and exhortations about its prevention and transmission. It is a specific human disease, unknown either naturally or experimentally among the lower animals, with a world-wide distribution that is unaffected by climate, season, occupation, race, age, or sex. Man has no natural immunity to it, and recovery from one attack does not confer any immunity upon the individual. The newly-born infant is as susceptible as the doddering old roué, and the tragedy about this and other venereal diseases is that the innocent child may suffer grievously for the fault of a parent.

The causal bacterium is a bean-shaped diplococcus, the gonococcus. It is called a diplococcus, because normally it is

seen under the microscope as a pair of cocci in apposition. The gonococcus is an obligate human parasite and has no free-living existence. It is a very delicate germ outside the human body and is rapidly destroyed by bright daylight, cold, drying, and most disinfectants in high dilution. It usually dies within a few hours outside the body, but under exceptionally favourable conditions it may survive for a day or two. The excuse so often offered to the doctor that the infection has been caught accidentally in a public urinal, or by contact with the seat of a public lavatory, is therefore ludicrous. Except in the case of infants and young children, 99·99 per cent. of gonorrhœal infections are contracted through sexual intercourse. The gonococcus is no respecter of persons, and sexual incontinence is not confined to any one class of society. Every case of gonorrhœa in the male after puberty, whether the patient is a duke or a dustman, means that some woman has also got the disease.

Several factors are contributory to the unhappy prevalence of gonorrhœa in Great Britain. Ignorance of, and curiosity about, sex matters; prostitution; drink, and our existing economic system, are the chief factors. It is a tragedy that so many boys and girls reach an age when the natural sex instincts begin to assert themselves without a clear and clean knowledge of a subject that vitally concerns the individual and the race. The fault lies principally with the parents. They have learnt by experience, and it should be their duty to see that their children know enough about sex matters to safeguard them from the risk of contracting venereal disease. We are suffering from an outworn puritanism that has long been degraded into prudery in this country. It is considered to be indelicate, unclean, or even obscene, to discuss sexual matters openly and honestly with our children, or among ourselves. The fact that sex is the motive power of much human activity ensures its frequent intrusion into our thoughts and emotions, but we dare not voice these thoughts, or discuss these emotions, because, if we do, our degenerate puritan tradition stigmatizes us as dirty-minded or sexually obsessed. The nation possesses, however, an inexhaustible repertoire of smutty stories with a sexual foundation, which circulate freely among all classes of society, and from which many children obtain the only information on sex matters that they receive before they are confronted with practical experiences. Many a marriage has been a failure from the start because the bride was completely ignorant about the implica-

tions of marriage, or because the bridegroom's only knowledge of marital behaviour has been gleaned from his acquaintance with the dubious jokes, often only partially understood, of older men. The position has improved somewhat in recent years, because most of our schools are now teaching the elements of biology to our children; but, without parental explanation, the child is rarely able to bridge the gap between the fertilization of a plant, or the procreation of a bird, and the processes responsible for its own being. After puberty, which usually occurs between 12 and 15 in the female and between 14 and 18 in the male, the natural maturation of the sex-glands engenders a natural—and normal—curiosity about sex matters in the adolescent. This curiosity can be satisfied by a clean, straightforward explanation of the physiology of sex and of the meaning of sexual intercourse that all parents ought to be able to give from their own experience. If this explanation is not given, the powerful sex impulses may lead the young man and woman to make personal experiments that may have disastrous consequences.

Prostitution is also almost as old as the human race. This is not the place to discuss the ethics of sexual conduct, but my experience as a medical officer of a Venereal Disease Clinic for some years led me to conclude that the prostitute is more often sinned against than sinning. Many women are driven to prostitution by betrayals which, in other spheres of human conduct, would come under the lash of the law, or earn the strong condemnation of society. Speaking as a bacteriologist, however, the prostitute is a constant and permanent menace to the community in the transmission of the veneral diseases, especially in this country, where conventional moral values outweigh the protection of individual and communal health. Our official attitude appears to be that prostitution is immoral, the prostitute is a degraded wanton, therefore she and her trade must be ignored. To recognize her ineradicable presence in human society, as it exists to-day, for reasons of health would be officially to condone, or even to encourage, immorality. It is a pity that we cannot take a common-sense view of prostitution for the sake of the health of the nation. In France, where they are no more immoral than we are, the prostitute is licensed and is kept under medical supervision and attention. Which is the greater danger to the mental, moral, and physical health of a people—to give official recognition to a tragic failing of human

nature, or, by omission, to encourage the dissemination of loathsome and dangerous disease? It has been authoritatively stated that 100 per cent. of prostitutes in Great Britain are, at some time in their careers, infected with, and carriers of, the germs of one or both of the two chief venereal diseases. Gonorrhœa is contracted very early in the career of most prostitutes —in some cases it determines prostitution—and unless medical treatment is begun at once the woman will probably become a chronic carrier of the gonococcus.

Alcohol depresses the higher centres of control in the brain and slows down the reflexes that regulate the various functions and activities of the body. The drunken man has lost his reasoning faculties and his power of judgment and has become merely an animal, swayed by those animal impulses that are dormant in each one of us but are normally controlled by the higher centres in the brain. Degrees of alcoholism short of drunkenness interfere with the individual's power of critical judgment in varying degree. Many a man, under the influence of alcohol, has spent a night with a prostitute whose company he would have shunned in his sober state. Many a woman, under the influence of alcohol, has yielded to the importunities of a man whose advances she would have repulsed in her sober state. There is no doubt whatever that alcohol is an important factor in the dissemination of the venereal diseases.

When I worked in a Clinic years ago, I was made aware of a terrible fallacy that was current among the less educated and intelligent section of the population—that a cure for gonorrhœa was to have sexual intercourse with a virgin of the opposite sex. It is, of course, utterly absurd; but it was responsible for a number of cases of the disease that came under my personal observation. I can only hope that the fallacy is dying out with the better education of that section of the population.

Gonorrhœa is not usually an immediate danger to life; although the gonococcus can produce a rapidly fatal septicæmia on occasion. The remote consequences are the more important and the more tragic, both for the individual and for the nation. Absolute sterility in either sex; crippling chronic inflammatory lesions of the joints in either sex; blindness in infancy; inflammatory occlusion of the penile portion of the urethra (stricture of the urethra) in the male; chronic inflammation and enlargement of the prostate gland in the male, and chronic pelvic inflammation—resulting in semi-invalidism—in the female are

among the possible sequelæ. Stricture of the urethra and prostatic enlargement often lead ultimately to serious interference with the excretion of the urine and, by back-pressure action, to impairment of the renal (*i.e.*, kidney) function. Both conditions often necessitate the performance of serious surgical operations in later middle life. Non-venereal enlargement of the prostate gland is, however, common in men over the age of 50 who have lived clean and upright lives. It must not be regarded, therefore, as invariably indicative of a youthful sowing of wild oats.

The infant is infected during the process of its birth by direct contact with the gonococcus in the maternal birth-canal. The germ attacks the covering membrane of the eye, the conjunctiva, and complete blindness results if the disease is not promptly diagnosed and properly treated. Infantile gonorrhœal conjunctivitis still helps to fill our Blind Institutions. Young children may be infected by sleeping in the same bed with a gonorrhœal parent, by bathing in the same bath-water, or by using the same towel, or sponge. Young girls may be infected as a result of a criminal assault. A female child carrier of the germ may also provoke an epidemic among girls in orphanages, hostels, and hospitals, as a result of the faulty, communal use of toilet articles. Gonorrhœal infection in girls before puberty often sets up a chronic, intractable inflammation of the genital tract.

Gonorrhœa is largely a voluntary disease; it is also largely preventible. Most acute cases in the male can be cured if medical treatment is begun at once, but prolonged treatment is often necessary. Once the gonococcus is implanted in the tissues of the human body, it acquires a high resistance to chemical disinfectants and to the specific anti-bodies made by the tissues. If the acute phase is allowed to pass into the chronic phase of " gleet ", before the patient seeks medical help, treatment is much less successful and is always lengthy and unpleasant. As a rule, women do not experience as much local or general disturbance of health during the acute phase as men, and they are therefore less inclined to seek medical advice and treatment. The social stigma that attaches to the venereal diseases in this country makes both men and women afraid to approach the doctor, especially since the Law has ruled that professional confidences are not privileged in our Courts of Law. Not all the victims of venereal disease are criminals, profligates.

or wantons; many are good citizens who have unfortunately fallen by the way. A helping hand and an understanding sympathy will often restore their self-respect and renew their self-control.

The acute disease generally prevents the male from indulging in sexual intercourse, but this inhibition often does not operate in the female. The result is that women are more dangerous disseminators of the disease than men. Moreover, in both its acute and its chronic phase gonorrhœa is more difficult to eradicate in woman than in man, and many women who have contracted the disease become permanent carriers of the germ and persistent foci for the dissemination of the disease.

Prevention can be secured for the individual and for the community by (*a*) a universal dissemination of a proper knowledge of the physiology of sex among young adults; (*b*) the medical control of prostitutes; (*c*) individual self-control and sexual continence before marriage; (*d*) the institution of certificates of health of the contracting parties before marriage, and (*e*) in those persons in whom abnormally strong sex impulses make absolute sexual continence almost a physical impossibility, and our present economic system makes marriage impossible, the employment of special preventive measures under medical control and advice.

Syphilis is a much more dangerous and loathsome disease than gonorrhœa, and has been rightly called the worst scourge of mankind. Medical authorities are generally agreed that it was unknown in Europe, Asia, and Africa before the return of Columbus from his discovery of America. The home of the disease was apparently in the West Indies. After its introduction to Europe by Columbus's sailors, who were infected by sexual intercourse with the native women of Cuba, it spread with great rapidity throughout the Continent, and has now a world-wide distribution that is independent of climate or season. No race, no class, no age, and neither sex, are exempt. Man has no natural immunity to it, and recovery from one attack does not protect against a subsequent attack. The individual does develop some degree of resistance, however, because so long as the causal germ remains in the body he cannot be re-infected from external sources. Transmission of the disease is by direct contact during sexual intercourse in most cases; but the causal germ is excreted in the male sex secretion, in the saliva, from special lesions in the skin, in human milk, and in the sweat,

and contact with any of these secretions from a syphilitic person will infect. Non-venereal infections are, however, extremely rare outside the family, with the exception of doctors, dentists, and nurses, who may be victimized through incautious handling and examination of syphilitic patients. The disease can also be inherited, and this is its most tragic feature.

The causal agent, *Treponema* (pronounced treppon-knee-mar) *pallidum*, is a spirochæte. It is an obligate human parasite, and syphilis is a specific human disease. It is quite incapable of any free-living existence and is a very delicate germ outside the human body, being rapidly destroyed by bright daylight, cold, drying, and dilute disinfectants. It is doubtful whether it can survive for more than a few hours outside the body under the best of conditions for its existence. The risk of contracting syphilis by contact with fomites is therefore remote, but it does sometimes arise. During the war of 1914–18 a young man of high character was a soldier somewhere in France and was billeted in a Nissen hut with fifteen other members of his unit. Unknown to him syphilis was rampant among his comrades. One day he drank from a mug immediately after one syphilitic, and in due course developed the primary lesion of the disease on his lip. Shortly after its appearance he went home on leave and, ignorant of his condition, infected his sweetheart when he kissed her. When eventually the true nature of the disease became clear to them, the young couple were only restrained with great difficulty from committing suicide. Such cases of non-venereal syphilis are extremely rare, but the syphilitic is always a menace to the community. *Treponema pallidum* develops an immensely increased resistance to drugs and disinfectants when it is lurking in the body-tissues, and the successful treatment of the disease always entails at least two to three years of willing co-operation between the patient and the doctor.

Syphilis is never an immediate danger to life in its early stages. If it were, it would be a much easier disease to control. It has a long incubation period that varies from 3 to 4 weeks in different individuals. The incubation period of gonorrhœa is short by comparison, varying from 2 to 7 days. The disease shows three distinct clinical stages—the primary, the secondary, and the tertiary. In its primary stage syphilis is apparently only a local and comparatively trivial disease. This is its chief danger, because the victim is not sufficiently alarmed to seek medical assistance at once, unless he has some knowledge of the terrible

nature of the disease and knows that he has exposed himself to the risk of infection. When the treponema is deposited upon the surface of the lining membranes of the genito-urinary tract, the lining membrane of the mouth, the conjunctiva, or in any breach in the continuity of the skin, it first causes the formation of a small, hard pimple (or papule in technical language), which is often painless and may pass unnoticed, especially in the female. The papule does not exhibit the cardinal signs of inflammation and no pus is formed in it, but sooner or later it breaks down into a painless, chronically-progressive, intractable ulcer which, if it is not treated in a special way, may steadily spread and eat away the surrounding tissues. This ulcer is known as the primary sore, or chancre (pronounced shanker), of syphilis.

Within a few hours of its implantation in the surface tissues, the treponema has entered the blood-stream and is rapidly distributed all over the body. It multiplies rapidly in the body-tissues and its activities result in the manifestations of the secondary stage of the disease. This stage develops at any time between 6 and 12 weeks after the appearance of the chancre. It is manifested by fever, sore throat, headaches, joint pains, malaise, peculiar skin lesions, and rashes of various kinds. The disease is rarely, if ever, fatal in this stage, and the individual is usually able to carry on with his daily work. The primary and secondary stages are both highly infective, but whereas infection in the primary stage is localized to contact with the chancre, in the secondary stage the blood, semen, milk, saliva, and sweat are all infectious.

The secondary stage gradually subsides spontaneously concurrently with the permanent localization of the treponema in one particular tissue or organ of the body. Here it remains dormant for a period that varies from 3 years up to as long as 20 years after the appearance of the chancre. Sooner or later, however, the untreated victim develops the terrible lesions of tertiary syphilis. These differ according to the tissue or organ that has been selected by the treponema, but in general they comprise intractable, progressive ulcerations, the formation of multiple tumours, and widespread degeneration and death of the tissues. The germ may select the skeletal tissues, and the victim suffers from painful chronic ulceration and destruction of the affected bones, with consequent crippling and disfiguring deformities. It may select the skin and underlying soft tissues, which are progressively eaten away by ulceration. It may

select the blood-vessels, the walls of which are so weakened that they balloon out under the pressure of the blood into huge thin-walled blisters that are technically known as aneurysms. Eventually the aneurysm bursts and the victim dies from internal hæmorrhage. It may select one of the internal organs—the liver, for example—which is slowly destroyed by the pressure action of tumour-like growths, or by progressive death of the individual tissue-cells. The most tragic victims are, however, those in whom the treponema selects the tissues of the brain or spinal cord, because these localizations result in the dreadful diseases of general paralysis of the insane and locomotor ataxy. If syphilis were eradicated from the British Isles, we could close down many of our asylums, because as many as 10 per cent. of the inmates are general paralytics. It is doubtful whether man can suffer from a more terrible acquired disease than general paralysis of the insane, although mercifully the victim is unconscious of his mental and moral deterioration and suffers little pain. Cancer may be an agonizing and a tragic disease, but it never causes the awful moral deterioration of general paralysis. The final stage of the general paralytic is that of the vegetable—life is still present, but that is all.

Congenital syphilis is one of the greatest tragedies to which childhood is subject. It is the atonement made by an innocent child for the sin of a parent. I use the word sin instead of fault deliberately in this context. No man or woman who has knowingly run the risk of syphilitic infection, or who has contracted the infection, has the right to procreate the species until medical science can confidently assert that he or she is no longer infective. The taint of syphilis can be passed on to the third and, possibly even the fourth, generation. The term congenital means that the infection is acquired by the unborn child in the womb of its mother. The original source of infection may be either parent, but the mother must be infected before she can infect her child. The treponema is able to pass in the circulation from the mother to the developing child in her womb. The result may be the premature birth of an undeveloped child (*i.e.*, an abortion, or a miscarriage); the birth of a child that is still-born; the birth of a living child already suffering from some mental or physical deformity, or the birth of a living child in which the seeds of syphilis are sown but are lying dormant. Such a child may manifest the disease in infancy and may, mercifully, die young. Or it may not manifest the disease until

later childhood, or puberty, or even early adult life. Fortunately the syphilitic child is usually born with certain stigmata that the doctor knows to be characteristic of the disease, and he is able therefore to give the innocent victim a prolonged course of special treatment that often permanently arrests the further progress of the disease. If the syphilitic child is not treated, it will develop any of the lesions that are seen in the tertiary stage of the acquired disease in the adult. It may be a mental and/or a moral degenerate from birth, or it may develop juvenile general paralysis of the insane, or juvenile locomotor ataxy, in childhood. It may be afflicted with gross bony deformities due to impaired formation of the bones, or to their destruction by ulceration. It may suffer from disfiguring destruction of the soft tissues and the skin, or it may develop a diseased condition of the internal organs. The symptoms and signs of syphilis, both in its acquired and in its congenital form, are protean, and the disease can simulate almost every other known human disease. Fortunately, medical science has evolved a highly specific test of the patient's blood which enables the doctor to make a confident diagnosis of syphilis in spite of its varied manifestations.

Syphilis is a voluntary disease in most cases; it is also a preventible disease. If it is properly treated in its primary stage, the further progress of the disease can be permanently arrested in the bulk of cases and the individual can be made non-infective. Syphilitic persons who have been properly treated in the primary stage can often safely be allowed to marry, but the treatment needs to be prolonged over several years and to be controlled by repeated blood tests throughout the life-time of the individual. Medical opinion is not united about the possibility of an absolute cure. Some doctors believe that the treponema can be eradicated from the body, if the proper treatment is begun early enough and is continued for a sufficient length of time. Others believe that the germ remains lurking in the body in small numbers throughout the life-time of its victim, but that it can be kept in permanent subjection by the appropriate treatment. Treatment is less successful in the secondary stage of the disease, but the further progress of the disease can be arrested in many cases. Treatment is least successful in the tertiary stage. The activities of the germ can be checked, but the damage that it has already done to the body before the disease was recognized cannot be repaired. Under careful medical supervision and treatment many tertiary patients may recover sufficiently to live

out a normal span of reasonably active life, but little can be done for advanced cases of general paralysis of the insane and locomotor ataxy.

It has been authoritatively stated that more than 10 per cent. of the population of the British Isles are syphilitics and that about 100,000 fresh infections occur annually. From 50 to 100 per cent. of prostitutes are infected, although those who have passed into the tertiary stage of the disease are not always infectious. The factors that are responsible for the spread of gonorrhœa operate also in the case of syphilis. The two diseases may co-exist in the same individual, and both infections can be acquired during the one act of intercourse. The same preventive measures that are available for the control of gonorrhœa are also available for the control of syphilis. No intelligent man or woman would knowingly and deliberately risk contracting a syphilitic infection if he or she were aware of the terrible nature of the disease. Ignorance is one of the principal allies of syphilis, another is alcohol. I hope that this short sketch of the disease, which is in no way exaggerated, may help to remove some of the conventional British screen of false modesty that shrouds this disease from public knowledge.

CHAPTER XIII

SOME RANDOM SAMPLING

CHILDBIRTH fever (puerperal sepsis) has attracted much official and public attention recently and some ill-founded criticism has been directed against the national Health Services, the medical profession, and the hospitals. It is good for the national conscience to be roused against a disease that is in many cases preventible; but it is wrong for that disease to be magnified out of all proportion to its relative importance for propaganda purposes. Puerperal fever is a dangerous disease and one that attacks exclusively a particularly important section of our population—the nursing mothers. The disease is not common, however, relative to the large number of pregnancies that are annually brought to a successful conclusion, and it is in no way comparable to rheumatic fever, tuberculosis, and the venereal diseases, for the harm it does to the nation.

Pregnancy is a strain upon the healthiest and strongest woman.

For nine months the prospective mother has to supply from her own bodily resources the demands of a rapidly growing parasite. It is true that the developing child is a natural parasite, but it is none the less a parasite because it lives on, and at the expense of, the nutrition, energy, and health of the mother. The birth of the first child is often also an exhausting process necessitating the expenditure of much muscular and nervous energy. The genital passages of the mother have to be greatly dilated to permit of the passage of the child, and in this process of dilatation they are liable to be bruised and torn. The puerperium therefore sometimes finds the woman mentally and physically exhausted, with injured tissues that are peculiarly susceptible to bacterial attack because of their diminished resistance.

The child is attached to the mother by a cord, the umbilical cord, which provides the vital connection between the maternal and the fœtal circulation. (The unborn child in the womb is called a fœtus—pronounced fee-tuss.) The cord enters the child's body at the umbilicus, or navel, and is connected at its other end to a special organ, the placenta, which is made by the maternal tissues specifically for the duration of the state of pregnancy. The placenta can be likened to a circular, flattened, rubber sponge filled with blood. It blends intimately with the tissues of the womb. After the child has been born and the umbilical cord has been cut to give it an independent existence, Nature has no further use for the placenta. It is accordingly expelled from the womb as the " after-birth ", usually within an hour of the birth of the child. Owing to its intimate connection to the womb, the expulsion of the placenta leaves a large, raw, bleeding surface in the womb. The womb, which has been enormously distended to house the growing child, shrinks rapidly after the expulsion of the after-birth. This contraction closes up the bleeding points and greatly reduces the area of the raw surface, but several days pass before the placental site is healed.

Bacteria are attracted to any dead or injured tissue in the human body. As I have mentioned in a previous chapter, germs not infrequently enter the blood-stream in small numbers, but ordinarily they are rapidly destroyed by the natural germicidal power of the blood. This destruction takes time, however, and if the germs are passively implanted in some injured tissue before the blood can destroy them, they are able to establish themselves because they are protected for a while from the

defensive mechanisms of the body. After childbirth every woman has an area of injured tissue in her womb, and some also have other injuries in their genital passages. All these injuries heal rapidly and successfully provided that they do not become infected with pathogenic germs. When germs are implanted in them they provide ideal conditions for the multiplication of the germs.

Pathogenic bacteria can reach the placental site in the womb by one, or both, of two pathways: (*a*) by way of the maternal blood-stream—endogenous infection, or (*b*) by way of the genital passages from sources outside the mother's body before, during, or after labour—exogenous infection. The mouth of the womb is tightly closed until labour commences, so that pathogenic germs lurking in the birth canal, or on the vulva, cannot enter the womb until the child has been expelled—*i.e.*, until the puerperium has begun. The mouth of the womb does not close after labour for several days, because the normal discharge from the placental site, the lochia, has to drain away.

The commonest causal agent of puerperal sepsis is a streptococcus, the same germ that causes scarlet fever, tonsillitis, and many other acute inflammatory and septic conditions in man. This germ has a liking for the tissues of the upper respiratory tract, and many healthy people carry it for variable periods in their nasal passages, or their throats. It is commonly associated with the common cold and with minor infections of the mouth and throat that often pass almost unnoticed. True carriers of the germ are numerous. If a woman shortly before labour develops a bad cold, or tonsillitis, or a "sore throat", or any septic trouble in her mouth, it is probable that the streptococcus will be present, even if it is not primarily responsible for the trouble. If the local trouble is severe, it may enter the blood-stream and be carried to the placental site. Medical opinion is now generally agreed, however, that such instances of endogenous infection are rare and constitute only a small percentage of cases of puerperal sepsis. A commoner autogenous infection results from the deposition of the germ on the woman's hands, either through the use of the insanitary pocket handkerchief, or by droplet contamination. It is surprising how often our fingers come into contact with our mouth, nose, and genital organs in the course of the twenty-four hours. The reader will, on reflection, appreciate the truth and significance of this statement. The streptococcus may therefore be transported from the upper

respiratory to the genital passages by the woman herself before, during, or after labour.

The streptococcus is a hardy germ outside the human body and can remain alive on bed-linen, clothing, towels, and in room dust, for several days under suitable conditions. Let us try to visualize two imaginary scenes that illustrate the ways in which exogenous infection can occur, because exogenous infection is now believed to be responsible for the bulk of cases of puerperal sepsis.

Mrs. X. is expecting her second baby within a day or two, and is wisely resting in bed. Her first-born, aged 3, naturally wonders what is wrong with his mummy and spends much of his time in and out of her bedroom. He has recently had a sore throat, or perhaps a cold, but his health and appetite do not appear to have been affected and the family does not pay much attention to his condition. From time to time, he coughs, or sneezes, in his mother's bedroom, and she wipes his nose for him with her handkerchief. When labour starts there are many ways by which the streptococcus that the child has distributed around the room can be deposited on the vulva, or in the birth canal, of the mother.

Mrs. Y. is expecting a baby very shortly. She has engaged a reliable midwife and has made all the necessary preparations for a safe confinement. The house is clean, the lying-in room free from dust, and she herself is in good health and spirits. A few days before her confinement the midwife develops a mild sore throat for a day or two, but it does not worry her much, and she goes to Mrs. Y. as soon as she is warned that labour has begun. While she is assisting Mrs. Y., it is impossible for her—unless she is wearing a mask—to prevent droplets from her upper respiratory passages falling upon her patient's genital organs. Both Mrs. X. and Mrs. Y. have now been exposed to the risk of infection and may develop puerperal sepsis.

In place of Tommy X. in the first illustration we can substitute Mr. X., or the housemaid (now known as the " domestic help " —if Mrs. X. is fortunate enough to have one these days), or Mrs. X.'s sister, or any relative, or friend, who has called in to commiserate with her and describe their own *alarming and agonizing* experiences when in labour. In place of the midwife in the second illustration we can substitute the doctor, the nurse, or any other person who attends to Mrs. Y. during her delivery and confinement.

The streptococcus is both a toxic and an invasive germ, and puerperal fever is both a toxic and an invasive disease. Either factor may predominate, or they may co-exist, but in most cases the invasive factor is the dominant one and the woman may succumb to a septicæmia if the invasion is not checked. In the past the disease had a high mortality rate and often occurred in disastrous epidemics. To-day medical science possesses effective remedies for its control, and its mortality rate has been greatly reduced within the last five years. The specific antitoxic serum, obtained by immunizing the horse against the streptococcal toxin, protects against the toxæmia, and chemical compounds of the sulphanilamide series exercise a specific check upon the invasion. Prevention is still, however, better than cure. How can the disease be prevented? Firstly, by the rigorous exclusion from the lying-in room, and from the immediate vicinity of the prospective mother during the last fortnight of her pregnancy, of any persons who have recently suffered from, or are still suffering with, any infection of the upper respiratory passages, or any septic infection or wound of the skin. Secondly, by prohibiting any doctor, student, midwife, or nurse with any similar infection from attending her during her labour and confinement. Thirdly, by the exercise of scrupulous cleanliness and antisepsis before, during, and after labour. Finally, by careful ante-natal examination of every pregnant woman to ensure that she is not harbouring the streptococcus.

The national Maternity Service is now fully alive to the precautions necessary for the prevention of puerperal sepsis, and the careful supervision of the personnel of the service by Medical Officers of Health has greatly reduced the incidence of the disease in recent years. The disease will never be abolished because "the best laid schemes o' mice and men gang aft a-gley", and accidents will happen, but its incidence can be reduced to the minimum. I hope that this explanation of the origins of the disease will perhaps help in its further reduction; but the reader must not jump to the conclusion that every person with a cold or a sore throat is harbouring the streptococcus. Until such a person has been proved to be free of the germ by a bacteriological examination, however, he or she must be regarded as a suspect. Finally, not every case of puerperal fever is caused by a streptococcus. Certain other bacteria may be the causal agents, but they are responsible for only a small proportion of the total number of cases.

Tetanus, popularly known as lock-jaw, is a comparatively rare disease among civilian populations in peace-time, but its incidence is increased in war-time, both among combatants and civilians under modern conditions of warfare. The reasons for this increased incidence will emerge in the course of this description of the disease.

The causal agent, *B. tetani*, is an anaërobic, spore-forming bacillus, whose normal habitat is the intestinal canal of animals, more especially herbivorous animals. It is quite often present in small numbers in the healthy human intestine. It leads a saprophytic existence in the intestinal canal and is excreted in the fæces, thereby becoming widely distributed in the soil, especially in the manured soils of gardens and allotments. It is doubtful whether the bacillus is able to multiply, or even survive for any length of time in the soil, but its spore is highly resistant to natural antagonistic agencies and can survive for many years in the soil. Although it is widespread in the soil, its distribution is uneven. It is absent from the soil of waste lands, mountains, and deserts, present in varying numbers in that of arable and pasture lands, and common in garden soil. Some English counties show a much higher incidence of human tetanus than others, owing partly to the uneven distribution of the spore and partly to the nature of the land. Cultivated and ploughed lands are more dangerous than meadow and pasture lands, because cultivation disturbs the soil and brings the spore to the surface where it may come into contact with man. Tetanus spores that are buried below grass and turf are rarely likely to make contact with man.

The disease of tetanus is a true toxæmia. The bacillus has little invasive power, but it makes a very powerful exotoxin, and all the symptoms of the disease are entirely referable to the action of this toxin. The spore is inert; it must germinate into the vegetative cell before the disease can develop, and germination is governed by numerous factors. Neither the bacillus nor its spore can penetrate the unbroken human skin or the membranes that line the various tracts and cavities of the body. There must therefore first be some breach in the continuity of the surface tissues and, as the bacillus is a strict anaërobe, the breach must be of such a nature that anaërobic conditions are provided in its depths. Puncture and stab wounds and severe lacerations provide the necessary anaërobic conditions. Abrasions, shallow cuts, and scratches are unfavour-

able to the germination of the spore because they are aërobic lesions. The presence of a foreign body in the wound, such as a thorn, a stone, a splinter of wood, glass, or metal, or a shell or bomb fragment, favours the germination of the spore. The presence of other bacteria, especially acid-forming germs and anaërobes, favours germination by reducing the oxygen tension in the wound and by lowering the local resistance. The presence of calcium salts—*i.e.*, earth, for all practical purposes—in the wound is apparently essential for the germination of the spore.

It is evident, therefore, that human tetanus can only arise when circumstances are favourable to the germination of the spore, and it is not often that all the necessary factors are present at the same time. The size of the wound is immaterial. The implantation of a rose thorn has lead to tetanus; but this is obviously a rare occurrence, otherwise the disease would be common in a land where gardening is a favourite hobby. In war-time conditions are more favourable for the development of the disease, because most war wounds are either deep, penetrating, or severely lacerated and are contaminated with earth, road dust, or fragments of dusty clothing. Moreover they often contain a foreign body.

After the spore has germinated, the bacillus multiplies at the local site and liberates its toxin. This has an affinity for certain cells of the nervous tissue. It does not spread over the body by way of the blood-stream; it travels up the nerves to the big nerve-trunks and then along these to the brain and spinal cord, destroying the affected cells as it goes. The characteristic sign of the disease, lock-jaw, results from an involuntary spasm of the muscles of the jaws brought about by the destruction of the cells in the centres in the brain that control those muscles. If the centres in the brain that control the vital respiratory and cardiac (heart) functions are destroyed, death is inevitable.

Medical science has provided us with an efficient prophylactic against tetanus toxin in the specific anti-toxic serum that is obtained by immunizing the horse with the toxin. Once the toxin has entered into a chemical combination with the cells of nerve tissue the anti-serum is powerless to neutralize it, but if the serum is given before this combination takes place in any of the vital centres the progress of the disease can be arrested. The best results are obtained when the anti-serum is used as a prophylactic, *i.e.*, when it is given as soon as a person with a suspicious wound comes under medical supervision. Every

dirty war wound must be regarded as a potential source of tetanus. War tetanus has ceased to be a serious menace under modern conditions of prophylaxis and treatment, and the disease is so rare in peace-time that it is not a cause for alarm. It is a wise precaution, however, for the individual to remove as soon as possible any thorns, splinters, dirt, or other foreign matter from any wound in the skin, however trivial it may seem to be. A thorn, or a splinter, can usually be removed in the home with a sterile needle, if it is a small one and not too deeply embedded—but the needle must be sterile. Choose a clean needle, free from rust, and sterilize it by immersion in vigorously boiling water for at least 15 minutes. Do not touch the point when removing it from the water. Rub the skin over the thorn with hot, soapy water, or a few drops of methylated spirits, extract the thorn, bathe the puncture wound with hot water, and then apply a drop or two of tincture of iodine. Cuts and abrasions that are contaminated with garden soil, or road dust, should be thoroughly washed with warm water and the dirt swabbed out with pieces of sterile cotton-wool. Allow the wound to bleed freely if it will. The bleeding washes out the germs that may be in its depths, and the germicidal power of the blood helps in their destruction. If the cut is a deep one, open it out deliberately and wash it out thoroughly with hot water. Finally, when the dirt has been removed, apply a dressing of "Elastoplast", or sterile lint, to protect it from further contamination. If it throbs (*after* 24 *hours*), or there is loss of sensation around it, with a stiffness of the surrounding muscles, go and see your doctor. If the foreign body is a large one, or the wound is severe and dirty, call in the doctor at once. The proportion of minor wounds of the skin that give rise to tetanus is probably not more than one in a million, but that is no reason why yours should be the one. The chances of contracting tetanus from the wounds that are an accompaniment of the ordinary daily life of the average citizen are almost infinitesimal compared with the chances of being injured by a motor vehicle. All the same, it is foolish to ignore any wound in the skin, or any foreign body embedded in it, because every breach in the continuity of the skin is a potential portal of entry for pathogenic germs, and any foreign body may be contaminated with them.

CHAPTER XIV

MORE RANDOM SAMPLING

THE human alimentary tract is the site of a number of serious bacterial diseases. This is not surprising, because the foods we eat and the fluids we drink are liable to be contaminated at any time by pathogenic germs. It is remarkable that the incidence of intestinal infections is as low as it is under normal conditions in the British Isles. Our relative freedom is due to a high standard of sanitation, a careful supervision of public water and food supplies, and a comparatively high average standard of personal and family hygiene. The British are an untidy people, but they are not a dirty people.

The chief intestinal infections met with in the British Isles are bacterial food poisoning, typhoid and paratyphoid fever, and dysentery. In some other lands, particularly in the Far East, cholera overshadows the combined effects of those diseases as a deadly scourge of mankind, but our islands have been free from it for centuries. Bacterial food poisoning and typhoid fever have already been discussed, and paratyphoid fever is, for our present purposes, merely a milder form of typhoid fever, although the causal bacterium is biologically distinct from *B. typhosus*.

Dysentery is the group name for any infective, inflammatory condition of the lower part of the intestinal canal that is manifested by the evacuation of blood and mucus in place of, or mixed with, the normal motions. Three distinct kinds of dysentery are known—

1. Bacillary dysentery, which has a world-wide distribution, and with which we are alone concerned here;
2. Amœbic dysentery, and
3. Balantidial dysentery.

Amœbic dysentery is confined to tropical climates. The causal agent is a microscopic, unicellular animal, *Entamœba histolytica*. *Balantidium coli*, the causal agent of balantidial dysentery, is also a microscopic, unicellular animal. It is a normal inhabitant of the intestinal canal of the pig, both domesticated and wild, and the human disease—which is rare—is an occupational disease of pig-breeders and slaughterers.

As far back as we can trace, bacillary dysentery has shared

with typhoid fever the reputation of being a scourge of armies and of civilian populations stricken by war. It is liable to break out wherever large numbers of human beings are crowded together under defective hygienic and sanitary conditions, and it is a common disease of those special aggregates of human beings that are gathered into asylums, prisons, and detention camps. Four biologically distinct species of closely-related, non-motile, non-sporing bacilli are responsible for the disease. These species are known by the names of the bacteriologists who discovered and studied them and are, respectively, *B. dysenteriæ* Shiga, Schmitz, Flexner, and Sonné. These bacilli are indistinguishable from one another under the microscope and in artificial culture in the laboratory. The Shiga and Schmitz bacilli can be distinguished from the Flexner and Sonné bacilli by their fermentative action on certain sugars, notably the sugar known as mannite, and each species can be identified and separated from the others by a study of its antigenic constitution, because each species has its own specific antigen. This study often takes a long time to complete, and it may be several days, or even weeks, before the bacteriologist is able to identify with certainty the particular species of dysentery bacillus responsible for a particular human infection. It is no use for either the doctor or the patient to become impatient over this delay. Bacteria are independent living things and they have their own rate of growth and reaction. Nothing that the bacteriologist can do will hurry them beyond a certain rate of development. Unfortunately, there are doctors who know so little about the general principles of Bacteriology that they constantly demand the impossible from their medical colleagues in the laboratory, and then brand them as incompetent because they cannot achieve it. These doctors are much more numerous among the ranks of the consultants than among those of the general practitioners, because the practitioner is generally aware of his own limitations and is prepared to co-operate with his colleague in the laboratory, whereas the consultant often fancies that he is omniscient and has nothing to learn from the bacteriologist. Bacillary dysentery is a disease that requires the closest co-operation between the clinician and the bacteriologist to secure the early identification of the causal agent, and an early diagnosis may mean the difference between life and death for the patient.

Two factors largely determine the incidence and dissemination of bacillary dysentery in any human community—(*a*) the presence

of human carriers of the germs, and (*b*) the presence of carrion flies. Apart from the dog, the disease is unknown naturally among the lower animals. The dog is susceptible to natural infection, and because of its intimate association with man it may assist in the spread of the disease. Unlike typhoid fever, dysentery is not essentially a water-borne disease, although water-borne epidemics do occur. In this connexion, some bacteriologists believe that wild-fowl, especially sea-gulls, can act as carriers of the dysentery bacilli, and that the contamination of water supplies by the excrement of these birds may be the explanation of some water-borne epidemics. It is a common sight to see flocks of sea-gulls far inland during the winter months in Great Britain, and the birds naturally tend to congregate around reservoirs, lakes, and rivers.

The dysentery bacilli are only able to infect man by one portal of entry, the mouth. The disease can therefore only arise from the ingestion of contaminated food and, as they are readily destroyed by heat, of uncooked foods. Milk, salad vegetables, and commercially prepared foods such as meat pies are the chief vehicles. The food may be contaminated either (*a*) by the fingers of a human carrier, or (*b*) by flies, and the contamination may occur in the factory, the warehouse, the shop, or the home. Fortunately the dysentery bacilli are delicate germs and usually die rapidly outside the body, generally within a few hours in the evacuated intestinal discharges. Infected flies may, however, harbour living bacilli in their food-canal for at least 24 hours. Flies simply act as mechanical carriers; the bacilli are not parasitic on them and do not multiply in their intestines. The dysentery bacilli are quite as sensitive as *B. typhosus* to the germicidal action of the acid gastric juice, and the gastric barrier therefore plays the same part in determining infection in dysentery as it does in typhoid fever.

Shiga dysentery is the severest and most dangerous of the four types, but it is normally restricted to the Tropics and the Far East, and does not occur in the British Isles. Human carriers may return to these islands from our tropical colonies and dominions, however, and potential foci of the disease may therefore be present in this country. Sporadic cases of Flexner dysentery occur annually in Great Britain and occasionally small epidemics break out. Sonné dysentery was originally confined to Scandinavia, but it is now the commonest form of bacillary dysentery in this country. Numerous sporadic cases

occur annually, especially in urban areas, and in some years true epidemics occur. It is the mildest of the four forms and is only rarely fatal. Schmitz dysentery is the rarest and, like Shiga's disease, is restricted to tropical countries.

No age and neither sex is exempt from bacillary dysentery, and man possesses no natural immunity to the disease, although wide variations in individual resistance are encountered. Recovery from one attack does not confer a solid immunity as is usually the case with typhoid fever. Sonné dysentery seems to attack children rather more frequently than adults in this country, especially in its epidemic form. Whichever species of bacillus is the causal agent, the disease is always localized to the large bowel—*i.e.*, the length of bowel between the appendix and the anus. (The appendix is a small, blind tube that juts out from the intestinal canal at the junction of the small, or upper, bowel with the large, or lower, bowel. Apart from providing the surgeon with a steady stream of work, it does not appear to be of any use to modern man. It is one of the relics scattered about our bodies of organs that once served some useful purpose, but have lost their usefulness with the progressive development of the human organism. In another million years or so it may have disappeared from the human body.) The dysentery bacilli are only feebly invasive and they never enter the blood-stream to become generally dispersed over the body. They produce their disease effects by the formation of powerful endotoxins and by their local destruction of the tissues of the bowel wall. The latter process is associated with a rapid and profuse diarrhœa that leads to rapid wasting and exhaustion through loss of water from the body-tissues. More than 60 per cent. of the weight of the human body consists of water, and the loss of any considerable proportion of this water content is inimical to life. Cholera and bacillary dysentery are the two bacterial diseases of man that are particularly associated with a rapid and profuse loss of the body-water. In cholera the loss is even more acute than in dysentery, and the body may be mummified through uncontrollable diarrhœa within 48 hours of the onset of the disease.

Shiga's bacillus makes both an exotoxin and an endotoxin, which partly explains why Shiga dysentery is more deadly than the other types. Individuals can be partially protected against the Shiga disease, however, by vaccination with the dead bacillus after it has been treated with formalin, and the degree of

protection obtained is of considerable value in epidemic times. A specific anti-serum obtained from the horse is also available for the treatment of Shiga infections and is effective if it is given early and in sufficient quantity. No specific prophylaxis or therapy is yet available for the other types of bacillary dysentery, but most cases recover under medical attention and careful nursing. The mortality rates of Flexner and Sonné dysentery are, respectively, generally less than 10 and 3 per cent. of those attacked. Many cases of Sonné dysentery are so mild that they are undoubtedly diagnosed by the clinician as "bilious attacks", or cases of "simple diarrhœa" due to dietetic indiscretions. The bacteriologist is the only person who can make an absolute diagnosis of bacillary dysentery and of the species responsible. Unfortunately many doctors only seek his assistance in the severe and/or prolonged cases of diarrhœa that come under their notice. The result is that many mild infections are missed, some of which become chronic carriers and potential foci of epidemic disease.

"Spotted fever" is the popular name for a disease that is known to the clinician as epidemic cerebro-spinal meningitis and to the bacteriologist as meningococcal meningitis. The causal agent, the meningococcus, is a bean-shaped diplococcus that is indistinguishable microscopically from the gonococcus. Like that germ, it is an obligate human parasite and an extremely delicate germ outside the human body. It dies out so rapidly outside the body that there is no risk of the transmission of the disease by contact with fomites. The human carrier of the meningococcus is solely responsible for the persistence of the disease and for its dissemination, and the disease is invariably transmitted by droplet infection or by direct contact with a carrier. Actual cases of the disease are not contagious and can be nursed with impunity.

The natural habitat of the meningococcus is the upper respiratory tract of man, more especially the region known as the naso-pharynx, which lies between the back of the nose and the roof of the mouth, and the commonest trouble that it causes is an inflammation of the lining membrane of the naso-pharynx. The degree of inflammation varies in different individuals from a mild catarrh, producing only a transient degree of discomfort and no general disturbance, to a severe inflammation with profuse pus formation that makes the individual feel decidedly ill. Most cases of meningococcal infection of the naso-pharynx

are diagnosed clinically as "sore throat", nasal catarrh, or a "bad cold". A diagnosis of influenza, or of an "influenzal cold", is very popular, but has little to justify it during inter-epidemic times, because true influenza is essentially an epidemic disease with definite characteristics. Various species of pathogenic germs can cause inflammatory infections of the naso-pharynx, and only the bacteriologist can show that any particular individual infection is due to the meningococcus.

In general, human beings appear to possess a relatively high natural resistance to the meningococcus, and many people harbour it in their naso-pharynx without showing any signs of local or general ill-health. Only in a very small proportion is the meningococcus able to spread from its local focus in the naso-pharynx and enter the blood-stream. We do not know for certain what conditions determine this spread in the individual, but there is evidence that pre-existing disease of the upper respiratory tract is a decisive factor. It acts by lowering the local resistance of the tissues, so allowing the meningococcus to pass through the natural barriers into the blood-stream. Once the germ has entered the blood-stream, it evinces a predilection for a particular part of the central nervous system, the meninges of the brain and spinal cord. The brain and cord are enclosed in a series of delicate, highly-vascular (*i.e.*, richly supplied with blood) membranes that are technically known as meninges. These membranes are separated from the brain and from each other by spaces filled with a special fluid, the cerebro-spinal fluid. The meningococcus sets up a violent inflammatory reaction in these membranes (meningitis), with the result that their functions are disorganized and their structure is damaged. The result of this change is that the normal circulation of the cerebro-spinal fluid is arrested and, consequently, the nutrition of the brain and spinal cord is seriously impaired. The brain, as I have already mentioned, controls all the manifold vital functions of the body, and therefore any gross interference with its nutrition and oxygen supply must inevitably lead to the death of the individual. Untreated meningococcal meningitis is always a very grave disease and has a very high mortality rate. Although no age is exempt, it is principally a disease of childhood and early adolescence, and the bulk of cases occur in individuals under the age of 25. Recent statistics indicate that from 60 to 80 per cent. of cases occur under the age of 16. The tragedy of the disease is not, however, its high mortality rate in the

untreated, but its high disability rate in those who spontaneously recover.

The brain houses within its substance several reservoirs through which the cerebro-spinal fluid normally circulates. These reservoirs, which are technically known as the ventricles of the brain, communicate with each other and with the spaces between the meninges by tiny openings, technically known as foramina. If these foramina become occluded by the inflammation caused by the meningococcus, the pressure inside the ventricles rises steadily because fluid is continually entering them from the brain-tissue, but none can escape. Eventually, the condition known technically as hydrocephalus, and popularly as "water on the brain", is produced. The higher centres in the brain that control our conscious life cannot function properly in the presence of this abnormal internal pressure, and the result is that the individual becomes partially paralysed, with an impaired mentality, and a huge head that has to be carefully protected throughout the rest of his or her life.

Fortunately, medical science has discovered effective remedies that will cure the disease and prevent the development of hydrocephalus in most cases, providing that the patient comes under medical supervision at a sufficiently early stage of the disease. Once the foramina are blocked no medical treatment can reopen them. A specific antimeningococcal serum can be prepared by immunizing the horse against the germ itself, and the prompt use of this serum will save most patients. There is also accumulating evidence that chemical compounds of the sulphanilamide type exert a curative action, if they are given in time. The present position is that meningococcal meningitis has been robbed of much of its terrors, but that complete control of the disease requires the willing and intelligent co-operation of the doctor, the bacteriologist, and the public.

Meningococcal meningitis is always liable to break out in epidemic form wherever large numbers of children and young adults are crowded together for any length of time, because it is essentially a disease of camps, barracks, and schools. The decisive factor in its spread is the nature of the sleeping accommodation that is provided. During the European war of 1914–18, widespread epidemics of the disease broke out in the army camps in Great Britain and, from the experience gained in the control of those epidemics, it is now known that the disease will not spread if there is a space of at least 6 feet between

adjacent beds. We know also that an epidemic will not commence until the human carrier rate has risen above 20 per cent. of the population. A large measure of individual protection can be obtained by avoiding overcrowding and by shunning crowded places such as cinemas, theatres, music-halls, and similar enclosed places of entertainment during epidemic times. The disease shows a seasonal prevalence in the late autumn and winter months, when infections of the human upper respiratory tract of all kinds are most numerous, and when people tend to crowd together for warmth, company, and entertainment. Gargling does not protect against the disease, however regularly and conscientiously it is performed, and nasal douching usually does more harm than good, unless it is done by an experienced surgeon.

During epidemic times a small percentage of those who are attacked by the meningococcus contract a fulminating, septicæmic infection and may die before any signs of meningitis appear. They are unfortunate individuals who are abnormally sensitive to the meningococcus. The germ multiplies with great rapidity in their blood, and colonies of it become arrested in the tiny blood-vessels in the skin. These plugs of germs are known as emboli. When a blood-vessel is suddenly plugged by a bacterial embolus, the sudden stoppage of the circulation causes a rapid rise in the pressure inside the vessel. This rise in pressure, combined with the damage done to the vessel wall by the activities of the germs, bursts the vessel and some blood leaks out into the surrounding tissues. The emboli are so numerous and the vessels so tiny that the patient's skin rapidly becomes profusely spotted with these small hæmorrhages. They show as reddish-purple spots under the skin, and their presence is responsible for the name "spotted fever". Although it is always a grave condition, spotted fever is not invariably fatal. Recovery can occur with prompt serum treatment and careful nursing, but the mortality rate is high.

CHAPTER XV

SOME ANIMAL VECTORS OF HUMAN BACTERIAL DISEASES

MAN has always depended to some extent upon the lower animals for his continued existence on this planet. In ancient times they served him principally as a more or less regular food supply, and he only came into contact with them at irregular intervals when hunting. The need for the preservation of certain animals arose as soon as man ceased to be a nomad and began to settle in permanent communities. Gradually, certain animal species became domesticated under these conditions, and this domestication has since enforced a constant and intimate degree of contact between man and certain species of animals. The congregation of human beings in permanent settlements introduces many complications into the problem of man's food supply, because both animal and vegetable foods have to be transported from the districts outside the settlement. The conservation of man's food and economic animals has become an increasingly important and difficult problem under modern conditions of life in large towns and cities. The death or disablement of his domestic animals seriously impairs his progress and welfare and directly influences his cost of living. Microbial diseases of our domestic animals therefore cause us severe economic loss and directly and indirectly exert an important influence upon our health and happiness. The problems presented by the microbial diseases of the lower animals as they affect man are separable into two groups:

1. Microbial diseases that are specific to the lower animals and are only of economic importance to man:
2. Microbial diseases of the lower animals that are transmissible to man.

Although the first group offers a fascinating field for study and discussion, we must confine ourselves here to a consideration of the second group and, in this group, to a consideration only of those diseases that are caused by bacteria. The lower animals may, however, sometimes act as mechanical, or passive, vectors of human pathogenic germs that do not cause specific diseases in them, and I shall include instances of these associations in my survey of the second group. I shall also include the vermin in this survey, because they are the most dangerous and therefore

the most important vectors of human bacterial diseases among the lower animals.

It appears probable that cattle were the first animals to be domesticated by man. They are certainly the most valuable of his domestic animals, supplying meat, milk, labour, clothing, and other important contributions to his progress and welfare. Cattle suffer from four important bacterial diseases that are transmissible to man: anthrax, tuberculosis, Salmonella infections, and contagious abortion. The first three have already been mentioned, and the last will be dealt with later on in this chapter. They may also harbour the streptococcus that is responsible for scarlet fever and puerperal sepsis, and the diphtheria bacillus, although the human diseases of scarlet fever and diphtheria do not occur among cattle. The cow's udder is often exposed to mechanical injuries and the skin surface consequently often bears cuts and scratches. If a milker is a carrier of either the streptococcus or the diphtheria bacillus, it is highly probable that the germ he carries will be deposited at some time on the cow's udder, because both these germs are carried in the upper respiratory passages and are ejected in droplets of saliva and mucus. They find suitable conditions for a semi-parasitic existence in the devitalized tissue of a breach in the skin of the udder. They do not invade the cow's tissues, but they multiply slowly in the cut, or scratch, and they may fall into the milking-pail during the milker's manipulation of the udder. The streptococcus is also able to live as a commensal in the teat canals of the udder. Human epidemics of both streptococcal tonsillitis and diphtheria have been disseminated by cows infected in this manner.

The horse and the mule are of great value to man as transport and draught animals and their economic value is considerable. The most important bacterial disease which they transmit to man is glanders, which is a deadly disease for both man and horse. The causal agent, *Bacillus mallei*, is a non-motile, non-sporing bacillus that is an obligate tissue parasite and has no free-living existence in nature. It is both a toxic and an invasive bacterium, forming an extremely powerful endotoxin. It invades the lungs, lymphatic tissue, skin, and nasal mucous membrane of the horse and, sooner or later, every glandered animal develops a muco-purulent nasal discharge in which the bacillus is expelled from the body. Through the continuous nasal discharge, extensive bacillary contamination of food, water,

and bedding may occur, and infection is most probably spread among horses by the eating of contaminated food, the bacillus entering the body by way of the alimentary tract. The disease, is encountered in one of two forms: an acute form, glanders, which is usually rapidly fatal, and a chronic form, farcy, which is much the commoner in the horse. An animal may recover completely from farcy, but only after a long period of ill-health that may extend over several years. A characteristic of the chronic form of the disease, both in the horse and in man, is that it may lie latent for long periods, sometimes for years, and then break out again violently when the victim is apparently recovered. The bacillus can also enter the animal body through any breach in the continuity of the skin, and animals may therefore also be infected by direct contact with the nasal discharge of a glandered animal. The acute form is the commoner in man and is a deadly disease with a mortality rate of over 60 per cent. *B. mallei* shows the same tissue localization in man as in the horse. Death is due in both cases to a widespread invasion of the lungs combined with a profound toxæmia. No specific treatment for the disease is available at present, but human glanders is not encountered among the general public. It is essentially an occupational disease, confined to grooms, farriers, knackers, and persons who work in close contact with horses. The disease has in recent years been eradicated from Great Britain as a result of (*a*) the great diminution of our equine population, owing to the replacement of the horse by mechanical agencies; (*b*) the use of a specific diagnostic test for the early diagnosis of the disease in horses; (*c*) the immediate slaughtering of glandered animals and the destruction of the carcases, and (*d*) the strict quarantine laws that regulate the importation of horses and mules into these islands.

Man does not usually come into such close contact with the pig as with the ox and the horse, but swine supply a considerable proportion of his flesh foods, and their skins and bristles are of economic value. They are susceptible to attack by the human variety of *B. tuberculosis* and are capable of transmitting the infection to man. They are also frequently attacked, sometimes in epidemic form, by bacilli of the Salmonella group, and undercooked pork, sausage-meat, and other pig flesh is the food that is most often implicated in outbreaks of human bacterial food poisoning of the invasive kind. These bacilli are also pathogenic for rats and mice, and the frequent contact between these vermin

and swine is partly responsible for the spread of infection among swine.

Sheep are less dangerous than our other food animals as transmitters of human bacterial diseases, although they are very susceptible to anthrax, and anthrax of the human lung (Wool-sorter's Disease) is a deadly occupational disease that is confined to sheep-shearers, wool-sorters, and persons who handle sheep-skins and wool in the raw state. Goats are almost as harmless as sheep, but they suffer from one disease that is transmissible to man from which sheep are immune. This is the disease known as Malta Fever, the causal agent of which is a small, non-motile, non-sporing bacillus, known as *Brucella melitensis*. The disease was originally confined to the goats in the Island of Malta but, owing to the milking value of those animals, which has resulted in their world-wide exportation, the disease has now a world-wide distribution. A very closely related bacillus, *Br. abortus*, is the causal agent of the natural disease of cattle known as contagious abortion, which causes severe economic loss to dairy-farmers and cattle-breeders in this country. Both germs are pathogenic for man and they give rise to a similar state of ill-health, the disease known as undulant fever. *Br. melitensis* causes at first a mild septicæmia in the goat, which produces little disturbance of the animal's general health, and then becomes selectively localised in the milk-glands of the female and the internal genital organs of the male as a tissue saprophyte. It is present intermittently in the blood of an infected goat and is excreted intermittently in the urine and constantly in the milk. Once this selective localization has occurred the animal shows no signs of disease and acts merely as a passive carrier of the bacillus. As a result of its excretion in the urine, the soil in the vicinity of goat farms becomes heavily and extensively contaminated with the germ. *Br. melitensis* has no free-living existence in nature, but it is quite a hardy germ outside the animal body and can survive for a long time in soil, dust, and water. It is able to enter the animal body through at least three portals—(*a*) the lining membrane of the alimentary tract; (*b*) the lining membrane of the genital tract, and (*c*) any breach in the continuity of the skin. Infection among goats is spread chiefly by the consumption of fodder contaminated with the bacillus in urine, or soil. Human infection is acquired in most cases by drinking unboiled infected goat's milk, or by eating cheese made from such milk, but some persons may be infected through skin wounds. In

man the germ shows a predilection for the lymphatic tissue of the body, and the disease produced by *Br. melitensis* is a chronic septicæmia, with intermittent fever, which may persist with intermissions for months or even years. The disease is rarely fatal of itself, but it has a high disability rate and the exhaustion resulting from the chronic toxæmia—due to the absorption of an endotoxin made by the bacillus—seriously lowers the patient's resistance and paves the way for other bacterial infections. The disease is not spread among humans by direct contact, and patients can therefore be safely nursed at home, or in any hospital. It is a self-limiting disease in man, and recovery is the rule, unless the patient's heart is damaged by the toxæmia, or he contracts some super-imposed infection. The bacillus invariably localizes itself in the female breast and is constantly excreted in the milk of nursing mothers. The control of human infections with *Br. melitensis* depends largely upon a strict public and private supervision of goat's milk and its products that are marketed for human consumption.

Brucella abortus is biologically so closely related to *Br. melitensis* that many bacteriologists now regard it as a variety of that bacterium that has adapted itself to a parasitic existence in a different species of animal host. There are two types of *Br. abortus*; the one infects cattle, and the other swine. The one is responsible for the serious economic disease of contagious abortion in pregnant cows, and the other causes the equally serious disease of contagious abortion in pregnant sows. The germ enters the animal body by the same routes as *Br. melitensis*, but infection is chiefly spread by the consumption of contaminated fodder. It also causes at first a septicæmia of a mild type, but it shows a predilection for the tissues of the womb and the milk-glands and is quickly localized in these situations. The localization of the bacillus in the womb of a pregnant cow (or sow) invariably results in the premature expulsion of a non-viable calf, *i.e.*, in an abortion. The germ is excreted in enormous numbers in the vaginal discharge that follows the abortion, with the result that extensive contamination of bedding and pasture-land occurs. Like *Br. melitensis*, it is capable of prolonged survival outside the animal body in soil, dust, and water, and once pasture-land has been contaminated it is a very difficult matter to prevent the disease from spreading throughout a herd. The germ soon dies out in the body of a healthy cow that is not pregnant, or in milk, but in both pregnant and lactat-

ing animals it settles down as a tissue saprophyte in the udder and milk-glands, where it may persist for many years. It is excreted intermittently in the milk of infected cows, and this excretion may persist for as long as seven years after the initial abortion. *Br. abortus* infection is widespread among British dairy cattle, and it has been authoritatively estimated that from 25 to 30 per cent. of our unpasteurized milk supplies contain the germ. Pasteurization makes the milk safe for consumption because the bacillus is easily destroyed by heat. Home boiling is also effective.

Br. abortus infection of man is so similar in its effects to *Br. melitensis* infection that only the bacteriologist can distinguish the type of infection in any particular case. Clinically the two infections are indistinguishable. *Br. abortus* infections are usually milder, but they show the same chronicity, the same tendency to relapse, and a similar disability rate to *Br. melitensis* infections. Although there is at present no specific treatment available for undulant fever, the outlook is good under medical supervision and careful nursing because the immediate mortality rate is low, less than 4 per cent. Convalescence is, however, slow, and the protracted fever predisposes the patient to intercurrent infections, so that the indirect mortality rate may be considerable in individuals who are not carefully nursed. Undulant fever is a rare disease in Great Britain in spite of the widespread distribution of *Br. abortus* in cow's milk. Although the germ generally enters the animal body by way of the alimentary tract, it is extremely doubtful whether human infection is normally acquired by the same route, because, if it were, we should expect it to be a relatively common disease in this country. It seems probable that most persons contract the disease through contact with material contaminated with the vaginal discharge of an aborted cow. The bacillus is apparently able to penetrate the unbroken skin under certain conditions, because veterinary surgeons almost invariably become infected when engaged for the first time in the removal of the retained products of conception (the after-birth) from an aborted cow. An occasional case of human infection may result from the repeated consumption of raw cow's milk heavily infected with the germ, but in the bulk of cases the disease is not a milk-borne infection. The moral is that any reader who has been, or is, unfortunate enough to contract undulant fever should not blame the farmer, or dairy, from which he obtains his milk in the absence of convincing

bacteriological proof that his infection is directly due to the consumption of that milk. As such proof is virtually impossible to obtain, the reader may be left to draw the obvious conclusion.

The dog enjoys the most intimate contact with man of all the lower animals, and it is therefore fortunate that it is not a transmitter of any specific bacterial disease to man. It is the transmitter of the very serious virus disease of rabies, or hydrophobia. The virus can only be transmitted by the bite of a mad dog, and must be implanted directly into human nervous tissue in order to produce the human disease. The dog is also solely responsible for the transmission to man of the dangerous hydatid disease, which is an infestation with the larval form of a small tapeworm that lives in the bowel of the dog in its adult state. The detailed consideration of these diseases is, however, outside the scope of this book.

The cat also enjoys intimate contact with man, but, like the dog, it does not transmit any specific bacterial disease to man. The cat population of these islands appears to be steadily increasing, owing to the animal's prolific breeding and the mistaken leniency of the State. The feline population would decrease with startling rapidity if the Government introduced a cat-licence, and we should be freed from the pest of cats that are allowed to wander about homeless. It is a pity that the Exchequer will not give serious consideration to the introduction of a cat-licence, because, although it would not bring in the revenue of the dog-licence, the cat is of little practical value to man in urban areas and a reduction in its numbers would be a definite benefit. The cat is susceptible to rabies, and cat-bites and scratches have a marked tendency to turn septic.

The vermin, which term comprises all the small rodents, especially the rat and the mouse, constitute one of the most serious menaces to man's existence on earth, because they transmit several deadly microbial diseases and are directly responsible for enormous economic losses. There are two main species of rats: the brown, or Norwegian, and the black. The latter is the aboriginal species of these islands, but its place has largely been usurped by the more savage and enterprising brown rat. This species is thoroughly at home in any human settlement, invading man's dwellings, workshops, granaries, and storehouses. It is a great traveller, and goes wherever man goes by the simple expedient of secreting itself in his belongings, merchandise, and means of transport. As it is an omnivorous

feeder and a most prolific breeder, its numbers are steadily increasing, and the rat population of the British Isles now probably equals, if it does not in fact exceed, the human population. The computation of the losses it causes by its spoilage of our stored foods and by its destructive habits is difficult, because so much of its activities are nocturnal and their effects are remote, but an authoritative estimate puts the figure at a minimum of £100,000,000 a year in Great Britain alone. As the brown rat is equally at home in a sewer and a dwelling-house and often passes directly from one to the other, it is a dangerous mechanical vector of the germs responsible for intestinal diseases in man. But its chief menace to man is that it is the natural reservoir for the causal bacterium of bubonic plague, *Pasteurella pestis*. From the earliest recorded times plague has headed the mortality lists of the human race. Not once, but on numerous occasions in the past, plague has come perilously near to exterminating the human race. The " Black Death " of the fourteenth century wiped out 25 million people in Europe alone, or roughly three-quarters of the population. Whole towns in Italy were completely denuded of their animal, as well as their human, populations, because most of the lower animals are susceptible to plague. Defoe's " Journal of the Plague Year " gives a vivid picture of the havoc and devastation caused by the last big epidemic of the disease in this country. Our relative freedom from plague since that time is the result of (*a*) better living conditions, especially as regards housing; (*b*) improved sanitation and personal and communal hygiene; (*c*) the provision of a national Health Service, and (*d*) the unceasing vigilance of our Port Authorities and their rigid control over all ships coming to this country from known plague ports abroad. We have the animal reservoir in abundance in this country and we do not possess any natural immunity against plague. We have to thank our island position and the conscientious work of the members of our Medical and Sanitary services at our sea and air-ports that the disease does not gain entrance to our land.

Every human epidemic of plague is preceded by an epizootic of the disease among the rat population. The transmission of the infection from the rat to man depends upon the intimate association of the rat, the rat flea, and man. This association is more likely to occur where there is squalor, dirt, and overcrowding. Every species of animal, including man ,has its own

species of flea, or fleas, which in general remain faithful ecto-parasites (*i.e.*, external parasites) on their particular host species and will not bite, or live on, the bodies of other animals of a different species. The rat is generously provided with fleas—it harbours four species—and all these will bite man if they cannot find a rat handy. The dog harbours two species, both of which will bite man, and then we have our own special flea, *Pulex irritans*.

The plague bacillus is spread among rats by the rat fleas and also by the cannibal habits of the rat. It produces a rapid and overwhelming septicæmia, so that in a short time the rat's blood is swarming with bacilli. The rat fleas suck up this blood, and a proportion of them develop a peculiar lesion in the alimentary tract. The proventriculus, a valvular structure between the flea's gullet and its stomach, becomes blocked with a solid plug of multiplying plague bacilli which have entered the flea's stomach in the rat's blood and have established themselves in that organ. When the proventriculus becomes blocked the flea cannot suck any more blood into its stomach and, as it lives entirely on blood, it soon becomes so ravenously hungry that it will attack any animal, man included, in default of its proper host. The flea sucks blood energetically and persistently until its gullet is enormously distended. The walls of the gullet possess considerable elasticity, but there is a limit to their capacity for distension, and eventually the elastic recoil of the walls forces the blood, now heavily contaminated with plague bacilli from the proventriculus, back into the puncture wound made in the animal's skin. The plague bacilli are thereby injected directly into the blood-stream of the animal and produce in it the same overwhelming septicæmia that occurs in the rat. The "blocked" fleas can live for many days without nourishment and they are highly infective. The infection is transmitted from man to man by the human flea, or by any other animal flea that bites man, for awhile, and then—and this is the most sinister feature of human plague—the disease changes from the bubonic to the pneumonic type. Pneumonic plague is probably the most infectious of any human bacterial disease, and it is this change in the character of the disease that is responsible for the appalling epidemics of the disease. Once the bacillus leaves the blood-stream for the lungs, it is disseminated by droplet infection and all that that implies in direct and indirect contact between human beings. The bacillus is also excreted in the

motions, the urine, and the discharges from ulcerating lymphatic glands, and these excretions may serve as vehicles for the dissemination of the bacillus and the spread of the disease. Bubonic plague has a high mortality rate, but recovery can occur. Pneumonic plague has almost a 100 per cent. mortality rate. No specific treatment is available for the disease, but a temporary and valuable protection can be conferred upon the individual by active immunization with a vaccine of the bacillus. The immunity thus obtained is only transient, but it is usually sufficient to protect the individual through an epidemic, and if it does not give complete protection it usually protects from a fatal infection.

As plague is carried by the rat and transmitted by the rat flea, preventive measures must aim at the extermination of the rat. This ideal is possible of attainment, but it will not be attained until mankind is fully alive to the menace of the rat and prepared to wage a world war against it. In the meantime, valuable work can be done by controlling the rat's activities as much as possible, more especially by preventing intimate contact between it and human communities. There are several endemic centres of plague in the world to-day, *i.e.*, centres in which the disease is always present, but in a sporadic form under ordinary conditions, and from these centres the disease tends to spread from time to time all over the world. Most of these centres are in remote parts of Asia, are situated in mountainous regions, and are inhabited by primitive peoples who live under grossly insanitary conditions in intimate association with their domestic animals, a state of affairs that is ideal for rat infestation. There is little fear of plague being introduced in epidemic form into these islands in times of peace, but an unscrupulous enemy might attempt to introduce the disease deliberately in time of war, although it is doubtful whether such an attempt would succeed.

The rat is also the natural reservoir for the causal agent of infective, or spirochætal, jaundice, which is another serious human disease with a high mortality rate. Mention has already been made of this disease, but I would emphasize here that the rat is solely responsible for its dissemination among human communities. The bite of the rat is also frequently followed by the disease of rat-bite fever, the causal agent of which is another spirochæte that normally lives as a tissue saprophyte in the rat. This disease is not usually fatal, but it has a high disability rate, and convalescence is often protracted.

The mouse is only a less serious pest than the rat by reason of its smaller size and slighter physical powers. It is just as prolific; it has similar habits, and it causes a proportionate amount of human disease and economic loss. Its spoilage of foodstuffs in the home alone causes severe economic loss to man. It is susceptible to most of the microbial diseases that affect the rat and is a close second to that animal as a menace to man. The evil influence of these vermin upon human health and progress is so serious and so costly that their organized and continual destruction ought to be one of the primary activities of the State. The annual rat week that is at present officially recognized in Great Britain is only a shade better than a farce. Fifty-two intensive rat weeks every year, waged with all the resources of the State and the intelligent co-operation of the public, would not be too great a price to pay for the control of these pests in our islands.

CHAPTER XVI

SOME INSECT VECTORS OF HUMAN BACTERIAL DISEASES

THE interrelations of man and insect are of great importance to human welfare and in some instances are decisive in their influence on human progress. Many insects are valuable allies of man, ensuring the fertilization of his crops and protecting him and his food supplies by preying upon injurious insects. Familiar examples of these beneficial activities can be seen on any sunny summer day in our gardens in the fertilization of flowers and fruiting plants by bees, butterflies, and other insects, and in the slaughter of various insect pests by wasps, ichneumon-flies, dragon-flies, and ladybird beetles. Considered as a whole, however, insects are generally regarded as our most dangerous animal enemies—to be, in fact, the only group of multicellular animals that is seriously disputing the habitation of this planet with man at the present time. They injure man either by their direct attack upon his person, his food animals, and his food plants, or by their indirect activities as transmitters of microbial diseases of man, animals, and plants. The harm they do is often so profound and persistent that it threatens man's existence, and at all times it is productive of severe economic loss. Man is at present unable to inhabit some of the most fertile regions

of the earth because of their populations of injurious insects, and in many other regions their presence makes his habitation precarious and hazardous. The total annual economic loss for which insects are responsible is so colossal that, if it could be computed with any degree of accuracy, its expression in figures would convey little to the mind. The depredations of the Colorado beetle alone amongst the world's potato crops must cause an annual loss of many millions of pounds, especially as in some areas the potato cannot now be cultivated because of this pest. The locust is capable of destroying every vestige of green vegetation over large tracts of land, and a plague of locusts may mean the complete loss of the staple food of a community, which may, in turn, mean famine and pestilence. In tropical countries the termite annually causes enormous economic losses by its ravages in timber, and there are many other insects that are as destructive in their own particular way. Fortunately the temperate climate of the British Isles is unfavourable to the propagation of many insects, and our insect pests are neither as numerous nor as formidable as those that live in tropical lands. Nevertheless, the agriculturalist, the stock-breeder, the industrialist, and the householder annually suffer heavy economic losses from the ravages of insects in these islands. The damage done by the gipsy moth to our fruit trees, by the crane fly (daddy longlegs) and other insects to our grasslands, by the greenflies (aphids) to our plants, by the bot and warble flies to our domestic animals, and by the clothes moths and carpet beetles to our homes and merchandise, is persistent and serious.

We must pass on, however, to consider insects in their rôle of transmitters of human bacterial diseases. The insects that are normally resident in Great Britain and are capable of transmitting bacterial diseases to man fall naturally into three groups:—

1. Ecto-parasites of man;
2. Predators;
3. Mechanical vectors.

There are three important resident external parasites of man—the bed-bug, the flea, and the louse. None of these insects is certainly the transmitter of a specific disease in Great Britain nowadays, but each may act as a mechanical vector of pathogenic germs, and their bites are liable to be followed by septic infections of varying severity. All three insects are voracious feeders on human blood, which is the sole food of the adults, and

in order to obtain their food they must puncture the human skin. The salivary secretion of these insects is highly irritant to the tissues and their bites are frequently followed by an intolerable itching that forces the victim to scratch vigorously. Pathogenic bacteria are often present on the fingers, especially under the finger-nails, and if these are inoculated into the puncture wounds, or into the scratches, serious infections may result. Individuals vary widely in their sensitivity to these parasites; some may be driven nearly frantic, others appear to suffer only slight inconvenience. In general, children are more sensitive than adults and consequently suffer more severely. I remember years ago seeing a baby whose entire body was covered with festering sores as a result of neglected bug bites. The child died after a long illness from exhaustion due to chronic sepsis and toxæmia.

The bed-bug is rapidly becoming scarce in this country, thanks to better housing conditions and a higher standard of family and personal cleanliness. When I was a medical student doing my midwifery course in a northern city, it was the custom to strip naked, while standing on sheets of newspaper, as soon as we returned from assisting another citizen into this world. Our average bag was seldom less than four of these loathsome insects. The American patronymic of "mahogany flat" accurately describes the appearance of the bed-bug, but it can be recognized infallibly by the intolerable, sweetish, fœtid odour that it emits when molested, or killed. It is a very active insect, running with remarkable speed over almost any surface. It is entirely nocturnal in its predatory activities, hiding during the day in cracks and crevices of all kinds in woodwork, walls and floors of rooms, behind wainscoting and pictures and loose wallpaper, on shelves, in cupboards, and in the mattresses and the framework of beds. It is a most persistent pest and will travel long distances to feed if necessary. The list of microbial diseases that it is potentially capable of transmitting to man is a formidable one—relapsing fever, kala-azar, tuberculosis, enteric fever, typhus fever, leprosy, anthrax, poliomyelitis, and plague, although it must be said in its favour that we only possess proof at present of its transmission of relapsing fever. Relapsing fever does not occur in the British Isles, and the bed-bug's chief danger to us is its responsibility for localized and generalized septic infections.

Most adults have had personal experience of the unwelcome

attentions of a flea because, unlike the bed-bug, which is a house-haunting pest, the flea lives in clothing and is widely distributed wherever people congregate. It breeds wherever organic dust is allowed to accumulate, and therefore the dusty house is liable to be flea-ridden. The adult can live for as long as four months without food, but the fertilized female must have a blood meal before she can lay her eggs. The insect shuns daylight, is attracted to warmth, and does not remain on the human skin when it is not feeding. The chief factors in the establishment of the flea in human dwellings are (*a*) lack of cleanliness, particularly the accumulation of dust; (*b*) the proximity of hen coops, kennels, and stables, in which the insect often breeds unchecked, and (*c*) the free access of flea-carriers, cats, dogs, rats, and mice, to the dwelling-house. Naphthalene is highly poisonous to fleas, and they can usually be eradicated from a room by scattering flake naphthalene over the floor and then shutting up the room for twenty-four hours. If a house, or outhouse, is heavily infested, the following emulsion, which is instantly fatal to the flea, can be used. Take 3 parts of soft soap, melt thoroughly by heat, and stir into 15 parts of water. Whilst still hot add 70 to 100 parts of petroleum, kerosene, or paraffin, **gradually,** with continuous shaking or stirring. The final mixture should be white and creamy with no free oil. Its efficiency depends upon the proper emulsification of the oil, which depends upon its gradual addition to the soap solution in the presence of continuous agitation. Before use, dilute to 1 in 20 with water. This mixture can be used as a wash, a spray, or a rub.

Individuals vary widely in their reaction to the bite of the flea. Some who are abnormally sensitive may develop generalized rashes and constitutional symptoms; others develop local symptoms of varying severity, and some suffer little inconvenience. As a rule, however, the bitten spot itches and the victim is driven to scratch it, with the consequent danger of introducing pathogenic germs into the puncture wound. Eucalyptus ointment seems to allay the itching in many cases. The chief danger of the flea to man is that it is the transmitter of bubonic plague.

There are three forms of human lice, the Head-louse, the Body-louse, and the Crab-louse, and they confine themselves with remarkable constancy to their respective preserves. The crab-louse anchors itself to the hairs on the genitals and in the armpits; the head-louse to the hairs on the head, and the body-louse

resides in the clothing that is worn next to the skin, or anchors itself to the hairs on the trunk of hirsute individuals. They are relatively delicate parasites that cannot survive for long away from the human body. They cling tightly to the hairs, feeding more or less continuously on the host's blood, and rarely move about much while their host is alive. The crab-louse in particular remains practically stationary, rarely moving more than two inches from its birthplace throughout its lifetime. The eggs, or nits, are firmly glued to the hairs by the female and are visible to the naked eye as small white beads on the hairs. Head-lice are commoner on the female, body- and crab-lice on the male, although all three forms may be found on the same individual.

Louse infestation occurs where there is overcrowding, poverty, squalor, and dirt. They may attack the most cleanly person, because the eggs are widely dispersed attached to shed hairs in latrines, public baths, gymnasiums, sports pavilions, and other places where the clothing of the individual is removed in public. Their feeding leads to persistent irritation and consequent scratching, and it is rare to find a lousy person who is not suffering from some degree of skin sepsis. The head-louse is often indirectly responsible for the serious skin disease of impetigo in children. This is a chronic staphylococcal infection of the skin of the scalp, which if untreated may spread over the face and body. The septic spots become covered with repulsive scabs, from under which a purulent, infective discharge oozes, and the accompanying toxæmia may seriously undermine the child's general health. The fallacy still persists among the less educated and intelligent section of the public that head-louse infestation in a child is a sign of good health. The parents argue that if the child can provide sustenance for the parasite he or she must be in a good state of health. The reader may feel that this statement requires to be taken with a grain of salt, but I can assure him that it is true. I believe our national bill for education is in the region of £80,000,000 a year. When one encounters fallacies like this still held by citizens who have received the benefit of a free education, one is inclined to wonder sometimes whether the nation is getting full value for its money.

Apart from its indirect responsibility for septic infections of the skin, the louse transmits to man the deadly disease of typhus fever and the crippling disease of trench fever that was prevalent among our troops in Flanders during the war of 1914–18. Typhus fever is essentially a disease of low civilization, of

insanitary, overcrowded living conditions, and of poverty and dirt. It has been eradicated from most European countries in times of peace, but it tends to reappear in war-time and during any period of national distress and famine. It is a disease of cold and temperate climates and is prevalent during the winter months when human dwellings are more crowded, clothes are less often changed and washed, and there are more opportunities for the spread of lice. The disease is caused by a minute, rod-like organism, known as *Rickettsia prowazceki* (from the surnames of two medical men, Drs. Ricketts and Prowazcek, who gave their lives in the study of the disease), which some bacteriologists list with the viruses and others with the protozoa.

The predators of man comprise the blood-sucking flies, such as the gad-fly, the stable-fly, the mosquito (or gnat), and the midge, and certain other blood-sucking insects that are not of importance in the British Isles. The mosquito is the most dangerous of these insects, although it does not transmit malaria in this country nowadays because our average annual temperature is a few degrees below the minimum viable temperature of the protozoan parasite that is responsible for the disease. The Briton considers that the climate of his islands provides him with adequate reasons for a perennial grumble, and the vagaries of our weather afford him his chief topic of casual conversation. We ought to be unfeignedly thankful to our climate, however, if only because it protects us from malaria, which many authorities believe to be the worst scourge of mankind. The world death rate from malaria has been estimated at two million people annually, and the annual economic loss to the British Empire alone at from £50,000,000 to £60,000,000. In Great Britain the mosquito is not responsible for the direct transmission of any specific bacterial disease, but it causes much annoyance by its direct attack on our persons, and indirectly it is responsible for a certain amount of disease. The effects of a mosquito's bite vary widely according to the individual's sensitivity. Little children generally suffer more severely than adults and often experience severe and persistent irritation that leads to almost uncontrollable scratching. Black iodine ointment often rapidly allays the irritation and, if well rubbed in, protects against sepsis. Eucalyptus ointment is also soothing and protective. If neither ointment is available, the puncture wound made by the insect should be covered with a piece of adhesive, antiseptic plaster to prevent the individual from scratching it and to protect it against

germs and dirt. Only the female sucks blood, the male—as in the human species—is a harmless fellow who spends his time dancing attendance on his partner. The female must have a meal of blood before she can lay her eggs, and the instinctive urge for oviposition makes her a most persistent and fearless predator.

The larva of the mosquito is aquatic and lives its life in still collections of fresh water, or at the edges of sluggish, reedy streams. Marsh and fen lands provide favourite breeding-grounds, but the insect will also breed freely in rain-water barrels, in the choked gutters of houses, and even in small collections of water in discarded tins and bottles. Certain species of top-feeding fish of the minnow kind feed on the larvæ, but, as the female can lay several hundreds of eggs at a time, and as some species can breed continuously throughout the year, natural agencies barely hold the insect in check. The mosquito can be eradicated from a region by organized and sustained human effort, as has been shown by the brilliant results achieved by the Americans in the Panama Canal zone. Drainage and cultivation where the land will repay the expense, permanent and complete flooding where it will not; the proper paving and draining of human settlements; the filling-in of stagnant pools; the cleaning and clearing of the banks of sluggish streams; the covering of large collections of still water with films of oil at regular intervals, and the protection or abolition of all local household accumulations of fresh water, are effective measures for the control of the mosquito.

The midge is only less of a nuisance than the mosquito by reason of its smaller size and the smaller puncture wound it makes in the human skin. Its physical inferiority is counter-balanced by its greater numbers, by its relative invisibility, and by the silence and stealth of its attack. Some persons hardly dare sit out-of-doors after sunset on a summer evening because of their sensitivity to midge bites. The bite raises a firm swelling that itches intolerably, especially when the individual sits in a warm room, or lies in bed. The temptation to scratch the spot is almost irresistible, but the result may be a septic infection that may range in severity from local abscess formation to a rapidly fatal septicæmia, depending upon the bacterial flora that the individual carries under the finger-nails. I do not know of any preparation that can be applied to the skin that will certainly keep away mosquitoes and midges. Oil of lavender is reputed

to be efficacious, but I have not found it protective. Eucalyptus ointment has proved more effective in my experience, but it is greasy and liable to stain the clothing.

The most dangerous insect transmitters of human bacterial diseases in Great Britain are to be found in the third group, and comprise the various species of carrion flies, the common house-fly, the stable-fly, and the bluebottle and greenbottle flies. The stable-fly resembles the house-fly in appearance and is responsible for the erroneous complaint, occasionally heard, that a person has been bitten by a housefly. All these insects breed in human and animal manure, or in the cadavers of animals, and they feed greedily on excrement, offal, putrefying flesh, and most human foodstuffs. As I have already emphasized, the house-fly is the most dangerous of our insect pests in relation to the transmission of human bacterial diseases. It does not possess a single redeeming feature. It is neither useful nor ornamental, and at all times it is a nuisance to man and beast. Most of the pathogenic bacteria, fungi, and protozoa that infect man are able to pass through the fly's intestinal canal unaltered, at least within certain time limits. It has been found by the examination of captured flies that this limit is 4 days for the dysentery bacilli and 8 to 10 days for *B. anthracis* and *B. tuberculosis*. Dr. Wenyon, working in Alexandria in 1916, found in the excrement of captured house-flies the cysts of *Entamœba histolytica* and *Giardia intestinalis*, and the eggs of *Ancylostoma duodenale*, *Tænia saginata*, *Trichuris trichura*, *Heterophyes heterophyes*, and *Schistosoma mansoni*, all of which are intestinal, animal parasites of man. If a fly that is carrying parasitic cysts, or ova, in its intestinal canal is drowned in water, milk, soup, or other liquid food, the life of the cysts and ova is prolonged. In addition to the pathogens already listed, the house-fly can also disseminate the causal bacteria of cholera, leprosy, and plague. *P. pestis* is actually transmitted from the larva through the pupal stage to the adult fly, as well as carried by the adult insect. The house-fly is also suspected of transmitting and disseminating summer diarrhœa—which is a serious disease of infants and little children—and it has been incriminated in the dissemination of small-pox.

It is doubtful whether any campaign for national physical fitness can be regarded as efficient unless it includes intensive propaganda against, and intelligent instruction about, the house-fly and the measures that can be taken to control it. The extermination of the insect is not an impossible task; its control

is certainly possible. It breeds in middens, in horse manure (its favourite breeding material), and in decaying vegetation. The abolition of its breeding places and the organized and persistent destruction of the adult insect in the dwelling-house, office, workshop, storehouse, and school, should be actively encouraged. The insect is naturally attracted to the light, and if imprisoned in a room at night invariably flies to the windows as soon as it is daylight. This instinct can be utilized for its destruction. The materials required are a very weak solution of formalin, about one-half per cent. concentration, a lump of sugar, and a saucer. Formalin is a deadly poison for the fly, but it has a pungent smell in strong solutions that will warn the insect away. Place the lump of sugar in the saucer and pour around it a tablespoonful of the weak formalin. Place the saucer on the window-sill just before leaving the room at night. In the morning any flies that are in the room will be attracted to the window and then to the sugar. The formalin solution is absorbed by the sugar, and when the fly attempts to feed on the sugar it is poisoned.

All foodstuffs in the home should be carefully screened from flies during the fly-season (May to October), and the compulsory screening of all uncooked foods exposed for sale should be enforced by law. It is not an uncommon sight to see wasps, flies, and bluebottles crawling over the meats, groceries, and confectioneries in our shops during the summer months, and the sight makes one wonder how a nation can expect to keep physically fit when it is prepared to tolerate such a preventible evil. The deaths that are due to the transmission of pathogenic bacteria by the house-fly probably exceed the annual mortality rate of puerperal sepsis, and it is a pity that they do not excite a proportionate concern on the part of the Government and the public.

CHAPTER XVII

WATER AS A SOURCE OF HUMAN BACTERIAL DISEASES

WATER is essential for all life on this planet, and the human organism needs a regular supply for the maintenance of its vital activities. Individual requirements of drinking-water vary widely, but there is a minimum limit of intake below which life is

insupportable for more than a few days. Most personal experiences record that thirst is far harder to endure than hunger. The human body consists of more than 60 per cent. of its weight of water, and as this content is continually being used up and lost by excretion, a steady replacement is necessary. Individuals and communities can adapt themselves to a minimum intake of water and can retain their health and activity under such conditions as long as their water supply is safe to drink. It is unwise, however, to reduce one's water intake to the minimum consistent with health, because a reserve of water is as important as a reserve of food. Many people drink too little water and their bodily functions suffer accordingly, because all of them depend upon an adequate supply of water for their effective performance.

In a densely populated and highly industrialized country such as England, where a large proportion of the population is congregated in cities and towns of varying size, the natural water supplies are often inadequate for the minimum needs of the urban community and have to be augmented by artificial means. Where the natural water supplies are adequate, they are often unsafe for human consumption and have to be purified before they can be used. The risk of dangerous pollution with human and/or animal excrement is ever present in all the natural surface water supplies in England, and no surface water is ever certainly safe to drink even in the remote moorland or mountainous regions of our country.

Pure water does not occur in nature, because all waters, both fresh and salt, contain organic and inorganic chemical compounds in solution and support some form of microscopic life. Under our existing legislation, all water authorities are required to provide and keep in any water-works invested in them a supply of "pure and wholesome" water. Sanitary authorities are required to see that every dwelling-house has a supply of "wholesome" water, and it is their duty to see that "the water in any well, tank, or cistern, public or private, or supplied to any public pump and used or likely to be used by man for drinking and domestic purposes" is not "so polluted as to be injurious to health". The law does not define the terms "pure and wholesome", but they have been defined by Sir Alexander Houston—a recognized international authority on water supplies—as indicative of water that is "in such a condition that it cannot cause typhoid fever, cholera, or other water-borne disease. It must also be free from chemical poisons and have no injurious

effects on metals. Further, it should be bright, clear, and sparkling, free from suspended matter, reasonably soft, and the salts in solution should not be present in excessive amount."

All drinking-water supplies come ultimately from the sea. In ways that are well known to the reader, the waters of the oceans are constantly falling on the land in the form of rain, hail, or snow, losing in the process their salt content. Rivers return the bulk of this water eventually to the sea, but some is naturally trapped in surface and subterranean lakes and pools, and some is artificially impounded in reservoirs and canals. As the fresh water falls from the clouds it picks up the impurities in the atmosphere that are soluble in it, and when it reaches the ground it picks up additional ones that vary according to the surface upon which it falls. The sources of all fresh water supplies fall into two classes—(*a*) surface waters, and (*b*) deep waters. The first class can be subdivided into (*a*) upland surface, derived from bare rock and uncultivated ground, and (*b*) moorland, derived from more undulating surfaces, some of which may be under cultivation or used as pasturage for sheep and cattle. Deep waters may be either artificially constructed deep wells, or springs that obtain their supplies from underground sources. Deep well-waters are generally much less liable to dangerous bacterial contamination than surface-waters, and upland surface waters are as a rule safer than moorland supplies. All deep supplies are formed either by the downward percolation of rain-water through the earth, or by the flow of surface water down natural clefts and fissures. Some kinds of subsoil are impervious to water, some are permeable in varying degree, others are so porous that they offer little obstruction to its passage. The semi-permeable strata act as efficient mechanical filters, so that by the time surface-water has filtered down through them it has lost most of its bacterial content and all its content of particulate inanimate matter. Some rocks, particularly chalk, are liable to crack, with the formation of extensive fissures down which surface-water may flow without undergoing any filtration. In chalk and limestone districts, therefore, even deep well-waters may not be safe from intermittent dangerous bacterial contamination, especially when periods of heavy rainfall succeed a drought that has dried the subsoil and induced fissuring.

Our national supplies of drinking-water are drawn from (*a*) lakes, either natural or artificial; (*b*) rivers and streams; (*c*) wells, deep or shallow; (*d*) springs, and (*e*) reservoirs, either open

or covered. Many of our cities and large towns draw their supplies from lakes, some of which have been artificially created by damming a mountain valley. Thus, Birmingham draws its main supply from artificial Lake Ruador in central Wales; Liverpool from the similar Lake Vyrnwy in the same region; Manchester and some of the Cumberland towns from the natural lakes in the Lake District, and Glasgow from natural Loch Katrine. These lakes are situated in uninhabited, uncultivated districts, and the surrounding land is protected for a variable distance from the incursions of human beings and cattle. This protected land comprises the gathering ground of the rain-water that feeds the lake, so that there is a minimal risk of accidental contamination of the lake, and the volume of water is so large that deliberate contamination would need to be on an impracticably large scale to pollute the city supply. The water has to be piped, however, from the lake to the city and then distributed to individual dwellings within the city. This distribution requires hundreds of miles of pipe-lines, and at times the water-mains are bound to run in close proximity to sewers and rain-water drains. Water-mains and sewers are liable to crack through natural stresses and strains, through the subsidence of the surrounding soil, through the vibration of traffic, and from certain other causes. If the two systems of pipes break at a point where they are running close together, dangerous pollution of the water may occur. Several epidemics of typhoid fever have been traced to a coincidence of this kind, but our Local Authorities are keenly alive to the danger, and the risk of a water-borne epidemic arising in this way in any particular town is slight.

Many of our cities and towns draw their supplies from rivers. London draws the bulk of its public supply from the Thames and Lea; Shrewsbury from the Severn, Nottingham from the Trent, and Rugby from the Avon. All these rivers are heavily polluted with dangerous bacteria and undesirable organic matter, and the water must be purified for human consumption. The purification process is a threefold one, comprising sedimentation, filtration, and chlorination. Gross organic matter is first precipitated from the water, which is then filtered—either through beds of sand or through mechanical filters—and finally chlorinated. This process can make a grossly polluted water safe to drink, providing that the three stages are properly controlled and are working efficiently. There appears to be some objection in the

public mind to chlorination treatment of a drinking-water. It is difficult to understand on what grounds this objection is founded, unless it is on ignorance, which is no excuse for it. Chlorine is a poison, and if unlimited amounts of it were simply bubbled, or poured into a supply, the public might have some cause for complaint. The modern chlorination process consists, however, in adding the minimum amount of chlorine that will make the water safe, and then neutralizing any free excess of it with ammonia, with the formation of harmless ammonium chloride, before the water is delivered to the public. In the minute amounts in which it is used, on an average about 0·5 part in a million parts of water, chlorine has no injurious effects upon human health, and its presence cannot be detected by the human senses. Chlorination of a water is the only certainly effective method of making a dangerous water safe to drink. It may fail under certain circumstances, but these are rarely encountered in Great Britain. There is little risk in this country of water-borne epidemics of bacterial disease arising from the use of treated river water, because the responsible authorities supervise the purification process with great care, and most of them control the various stages by regular and frequent bacteriological and chemical analyses of the water. Where such regular examinations are not carried out, it is usually because the responsible Council will not agree to finance the necessary analyses. "Many a good ship has been spoiled for the sake of a haporth of tar," is an old saying that may aptly be applied to those cases in which a Local Authority refuses to have regular and frequent analyses of its water supplies performed on the score of expense. No expense, within reason, should be spared to ensure that a vital commodity is above suspicion. A little truthful propaganda and some intelligent education will silence the criticisms of responsible citizens about the water rate.

Deep wells, more than 40 feet in depth, usually yield a safe drinking-water supply, except in chalk and limestone districts, where they may be intermittently polluted. The source of the pollution may be a long distance away from the well-head (see Fig. 5), because the pumping of the water from the well draws replacement water into the well by capillary attraction from the surrounding water-bearing stratum. The sinking of a deep well may cause fissuring of the surrounding strata, or may tap existing natural fissures. The safety of a deep well from dangerous bacterial contamination therefore depends upon (*a*) the

nature of the subsoil; (*b*) the location of the well, and (*c*) its structure.

Shallow wells are mostly suspect anywhere in England, and are often subject to undesirable contamination, although some yield consistently a wholesome supply. They are the supplies that give most trouble in this country and, unfortunately, they are the only supplies available in many country districts. They may be contaminated by surface-water washing into them during

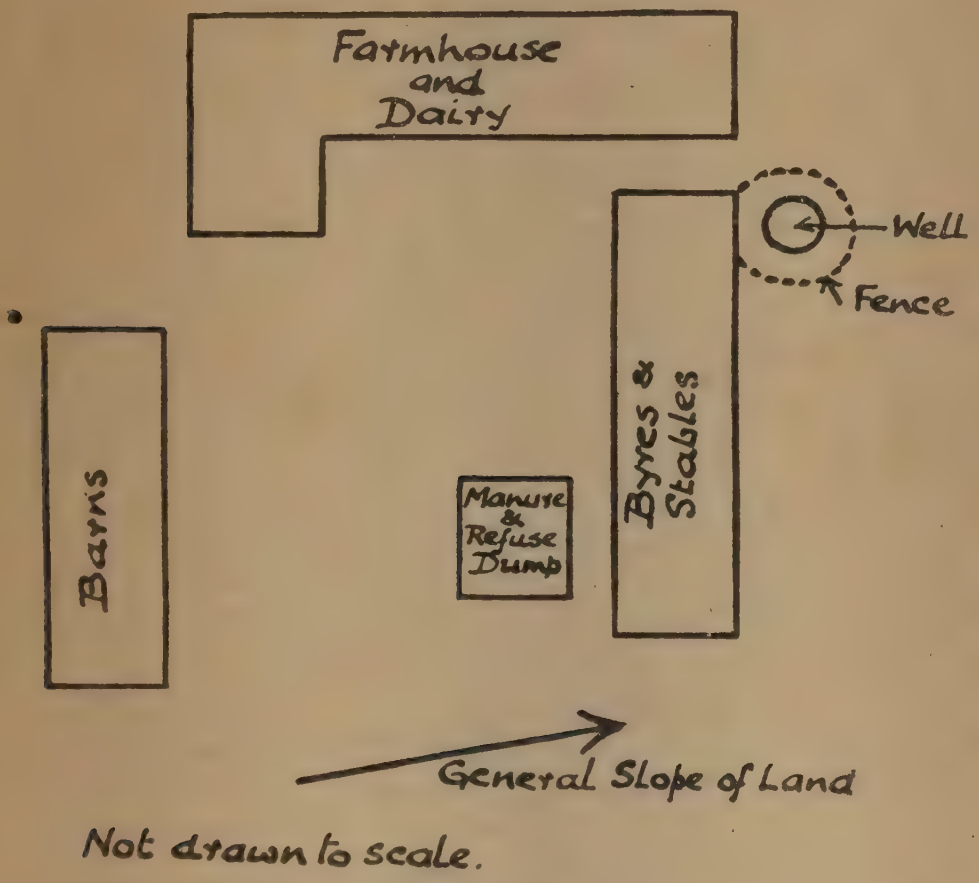


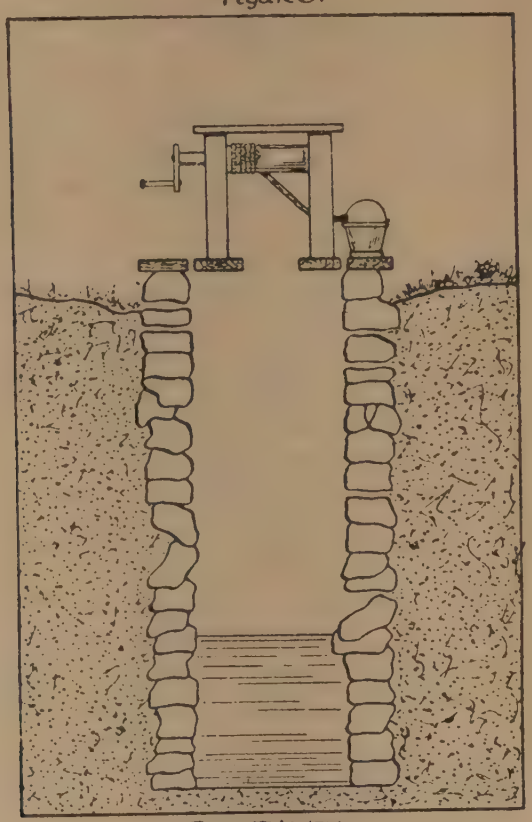
FIG. 2.

periods of heavy rainfall, by seepage of surface-water that has not been purified by filtration through a sufficient depth of subsoil, and by windblown soil and vegetation. Some years ago I was asked to examine the water from a shallow well that was the only drinking-water supply of a farm in a midland county. The farmer and his family had been drinking the water for years with no ill-effects, but holiday visitors to the farm were constantly falling ill with symptoms of intestinal infection, in some cases of dysenteric severity. The diagram in Figure 2 will enable the

reader to visualize the position of the well in relation to the farm buildings.

The laboratory analysis revealed that the water was in essence diluted manure-water, and an inspection of the premises showed that the well must have been drawing a part of its water supply from the liquid portion of the manure-dump in the farmyard. The farmer and his family had adapted themselves to the water by a process of gradual immunization, but newcomers with no such immunity suffered from the gross bacterial contamination of

Figure 3.

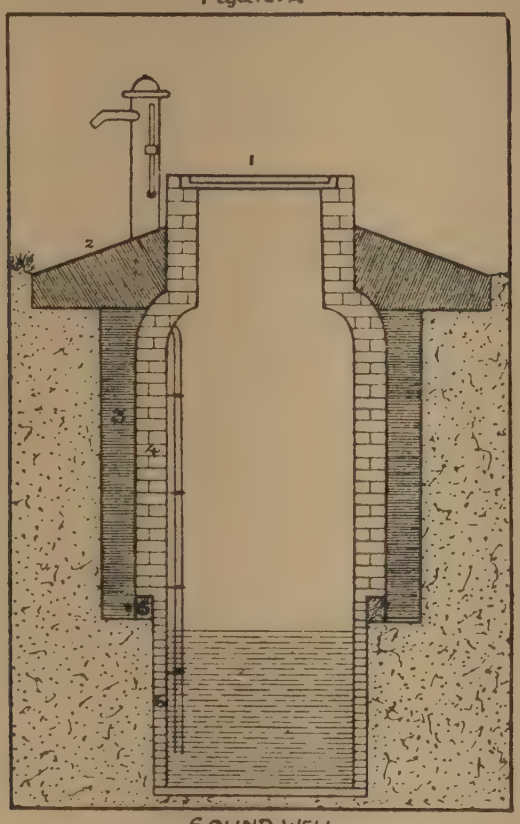


FAULTY WELL

the supply. This is an extreme example of the danger of a shallow well; but shallow wells that are situated near the banks of rivers, streams, and estuaries, near cess-pits and refuse-dumps, near human dwellings and animal houses, and in any built-up area, are liable to intermittent dangerous contamination unless their structure is such as to make them impervious to surface washings and wind-blown debris. The accompanying figures show, respectively, a cross-section of a defective and an efficient shallow well. Figure 3 is representative of many old wells that are still in use in country districts as supplies to private

houses, farms, and hamlets. Rain, surface-washings, wind-blown dust (often consisting of dried manurial matter) and vegetation, vermin, and insects, all have free access to the well. Surface-water can seep easily into the well at many points through gaps in the stone-work, and the shallow depth of soil is insufficient to provide any filtering action. Human sewage and animal manure deposited on the soil within a radius of 50 yards,

Figure 4.



SOUND WELL

1. Wood or iron cover.
2. Concrete apron.
3. 9 inch clay puddle.
4. 9 inch brickwork in cement.
5. Concrete.
6. 4½ inch brickwork laid dry.

at least, from the well are liable to pollute it during periods of heavy rainfall. If the reader will compare this figure with Figure 4, which shows the structure of a modern type of shallow well, the defects of the old type will be obvious.

Many townspeople nowadays are purchasing, or renting, houses and cottages in the country as week-end and holiday residences. Most of these dwellings draw their water supply from a shallow well, and the fact that the previous occupiers have drunk the water with impunity is often considered to be a guaran-

tee of its purity. This may be true in some cases, but in others it is incorrect. Largely through ignorance of the vital importance to health of a regular and adequate supply of wholesome drinking-water, many people pay little attention to the water supply of the country residence they wish to acquire. They make a careful inspection of the structural condition of the dwelling; they enquire particularly about its rateable value; they take note of its situation and appearance, and they are very particular about garage room for their car, but they give no thought to the most important feature of all, its water supply. No one should purchase a country house or cottage that is supplied from a shallow well without first having the well examined by a competent water engineer and samples of the water submitted to bacteriological and chemical analysis. If the water is pumped from the well to a storage tank in the roof of the house, this should also be carefully examined. In many cases it will be found to be an uncovered tank containing a rich sludge of wind-blown dirt and vegetation, bird excrement, drowned insects, often a decomposed bird or two, and sometimes a drowned rat, or other animal. The water from such a tank may be a rich soup, but it is not a wholesome drink. A further important point that is often overlooked is the nature of the piping that connects the well and/or the storage-tank with the house-taps. If lead piping is used and the well-water is soft, it may slowly dissolve the lead, and the family will suffer from the insidious effects of chronic lead poisoning, which is a very difficult condition to diagnose clinically. If the doctor is not told about the presence of lead piping, owing to the ignorance of the householder about his water supply, he cannot be blamed for failing to diagnose the family ill-health as due to lead poisoning. A few pounds spent on securing a safe and wholesome water supply in one's country cottage is often a wise economy. Nursing homes are not philanthropic institutions, and the medical expenses for a long period of ill-health are apt to make considerable inroads on one's income.

Many small towns and villages draw their supplies from springs, some of which consistently yield an adequate volume of wholesome water, while others are subject to intermittent contamination and are a source of anxiety. The purity of a spring-water is largely determined by the situation of the spring, the geological formation of the surrounding subsoil, and the depth from which the water rises. Springs arise where there are outcrops of

impermeable strata, or where geological faults bring permeable and impermeable strata into apposition. Figure 5 is a diagram of a cross-section of country showing the two ways in which springs are formed. The figure also illustrates the potential danger of a shallow well supply, because the one featured may obviously be contaminated either by seepage from the river, or by deposition of human and animal excrement on the surface of the soil at any point between the spring and the river bank.

The human bacterial diseases that are commonly water-borne are typhoid fever, cholera, and spirochætal jaundice. Occasionally paratyphoid fever and bacillary dysentery may also be water-borne, but in most outbreaks the responsible vehicle is milk or uncooked food. Cholera does not occur in the British Isles, and spirochætal jaundice is largely an occupational disease, so that, apart from non-specific inflammatory infections of the human intestinal tract resulting from the drinking of grossly contaminated water, the importance of water as a vehicle of human bacterial disease is practically restricted to the spread of typhoid fever.

Typhoid fever is a dangerous disease, with a high immediate mortality rate and a serious disability rate, for which no specific treatment is at present available. It is particularly a disease of late adolescence and early adult life, with a maximum incidence in the age group from 15 to 30 years, although no age is exempt. I have described it in detail in a previous chapter, but I would emphasize here that it is pre-eminently a water-borne disease and that human carriers of the germ are present throughout the population of these islands. Water-borne epidemics can therefore only be prevented by a ceaseless, conscientious supervision of public and private supplies, combined with intelligent co-operation and proper regard to their individual responsibilities on the part of the public. Chlorination is a valuable safeguard against the water-borne diseases and, with very rare exceptions, a chlorinated supply can be safely drunk anywhere and at any time.

Swimming is one of the healthiest of human exercises, and its popularity is steadily increasing in Great Britain, with the result that most inland cities and towns now possess, or are planning to provide, public swimming-baths. No swimmer, however expert he may be, can swim for any length of time even in the calm waters of a bath without swallowing some water. Moreover, however clean he may be in his person, bacteria from his

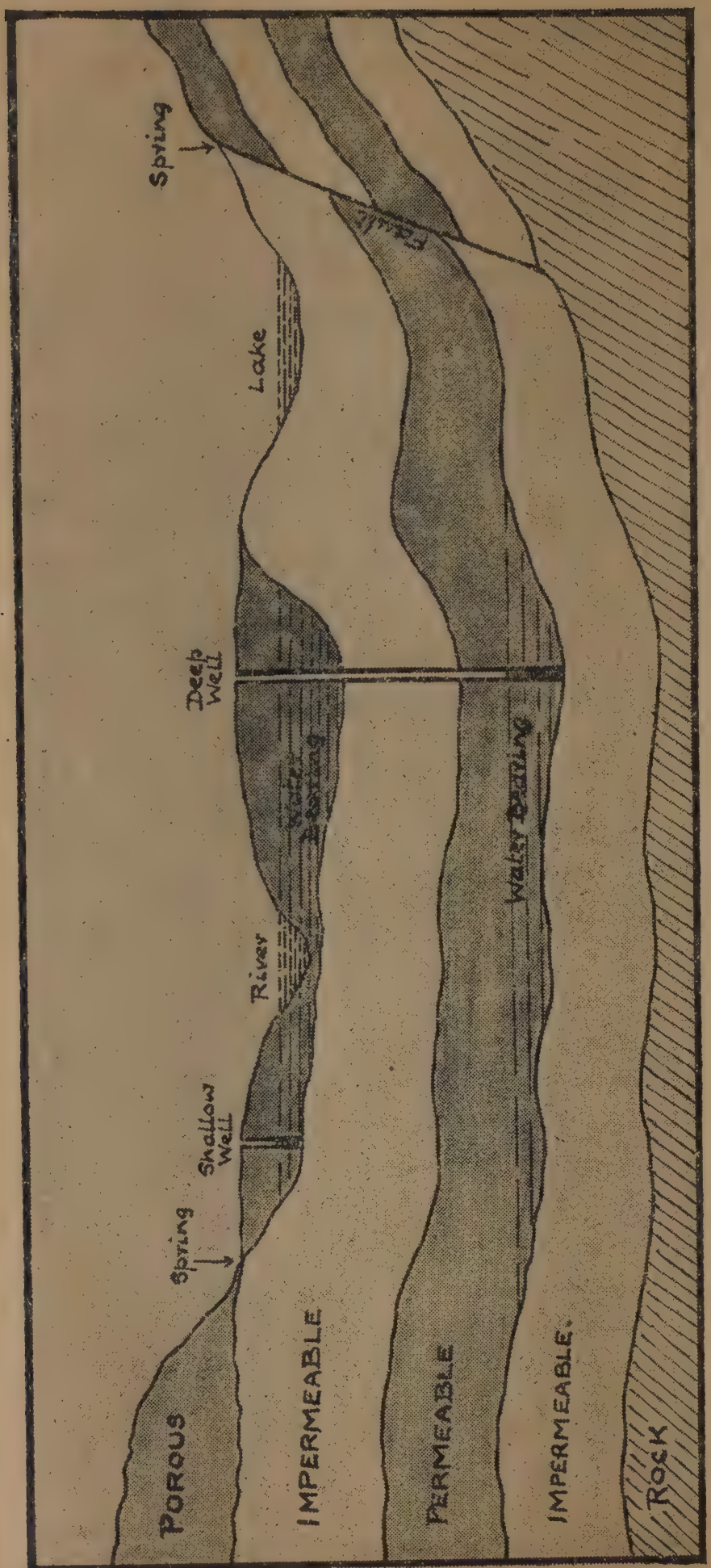

Spring
Lake
Deep Well
River
Shallow Well
Spring
POROUS
IMPERMEABLE
PERMEABLE
IMPERMEABLE.
ROCK

FIG. 5.

respiratory tract and from his skin, especially the skin surfaces around the anus and genital organs, are washed into the bath-water. Swimming-costumes are easily contaminated and, unless they are steam-sterilized after each bathe and are then properly dried and stored, will add a large number of germs to the water. At any time a human carrier of typhoid fever, dysentery, or some other bacterial disease may use the bath, and these carriers cannot be recognized by any ordinary examination. It is imperative therefore that the water in a public swimming-bath shall be so treated that at all times and under any conditions of usage it is safe to swallow. There is only one treatment that will provide this measure of security—chlorination. Chlorinated water is not as pleasant to swim in as pure, fresh water, or sea water, because the chlorine content that is required to give protection against a possible very heavy local contamination often causes slight temporary irritation of the delicate nasal and conjunctival membranes. Bloodshot eyes are common after a swim in a chlorinated bath, but the congestion quickly subsides and no harm is done. Individuals vary considerably in their sensitivity to chlorine and some cannot swim in a chlorinated water with any pleasure. People who oppose the chlorination of swimming-bath water do not realize that it is essential for the public health to have a water that is safe for all, although it may be unpleasant to some. It is wiser to have a safe chlorinated water than a water that is liable to spread typhoid fever, dysentery, and other infections. I am a keen swimmer myself, and regularly go twice a week to a public swimming-bath. I would never hesitate to swim in any chlorinated bath, or in the sea, but I would not swim in any of our English rivers at any time.

I have heard people complain that they have contracted nasal sinus and middle-ear infections from public swimming-baths. If the bath-water is chlorinated, they have not contracted their trouble through contact with living germs in the bath-water. The truth is that in most cases the individuals infect themselves, either through ignorance or carelessness. They enter the water carrying in their nasal passages pathogenic germs. Possibly they have recently had a cold, or a sore throat, from which they have clinically recovered, or they have been in contact with someone who has had an upper respiratory tract infection. Many people who can swim quite well to their own satisfaction have never been taught, or have never troubled to learn, the art of breathing correctly—in through the open mouth and out

through the nose—which is the first principle in swimming. If the swimmer does not breathe correctly, he is certain to draw some water forcibly into his nasal passages, and the inspiration of this water tends to wash the germs in those passages back into the nasal sinuses and into the Eustachian tubes. Faulty breathing also sets up abnormal pressures within the nasal passages, and if these contain any infective discharge it will be driven into the only channels of escape along the line of least resistance. Diving tends to have the same effect. Moreover some young people ask for trouble in their behaviour in the baths. As long as the body is immersed in water and the individual keeps moving there is no risk of chilling, even in cold water. If, however, the individual dives into the water and then climbs out and stands about, from time to time plunging in again for short periods, some degree of chilling inevitably occurs, even in an enclosed and heated bath. Chilling reduces the body's resistance to bacterial attack, and if the individual is carrying pathogenic germs in his upper respiratory tract they may become active and spread. It is a wise plan to use a swimming-bath to swim in, and to reserve display and foolery for hot summer weather at the sea-side, although even under these conditions there is still a risk of chill.

CHAPTER XVIII

MILK AS A SOURCE OF HUMAN BACTERIAL DISEASE

CLEAN, fresh milk drawn straight from a healthy cow is a valuable food for man at all ages, but modern conditions of life in industrial communities are such that freshly drawn milk is rarely available for consumption in urban areas. The collection of the milk in rural districts, often at a considerable distance from the urban consumer; the necessary pooling of the milk supplies from neighbouring farms to facilitate transport; the collection and transference of these supplies to distributing centres in our cities and towns, and the final distribution to the individual consumer, are all processes that increase the risk of contamination of the milk by bacteria that are pathogenic for man. Most of the spoilage of milk is caused by bacterial activity, and there is no article of human food that is more susceptible to bacterial contamination. In part, this is due to its delicate nature, because

the constituents are so delicately balanced that slight disturbances produce irreversible chemical reactions that completely alter its character. In part, its susceptibility is due to the numerous opportunities for heavy contamination that occur under the ordinary conditions of marketing in this country. Its rich content of nutritious substances makes it a favourable medium for the growth of most bacteria. Many of these produce visible alterations in it, but many human pathogens can multiply in it without causing any appreciable alteration in its appearance, taste, or smell.

Milk drawn fresh from a healthy cow under the cleanest conditions is never sterile. The external body cavities and the natural tracts of animals normally harbour bacteria, and a mixed population of germs is always present in the teat-canals and milk-ducts of the healthy cow. It has been found by examination that freshly drawn milk contains on an average about 20,000 germs per cubic centimetre. The extent and variety of this population vary with the conditions under which the animal is kept and with the care and attention given to the operation of milking. The population is reduced to its minimal limit when the byre, the bedding, and the hands and clothes of the milker are kept clean and the cow's hide, particularly on its flanks, is carefully cleaned immediately before milking. When the animal is kept under dirty conditions and the milker is ignorant and slovenly, the bacterial population of the udder increases enormously in number and variety. Cow dung has a teeming bacterial content, and a little of it can give rise to gross contamination of the animal's hide, udder, and milk.

The bacteria normally resident in the cow's udder are obligate tissue saprophytes and do not cause human disease. They do not seem able to multiply rapidly in clean milk that is stored at low temperatures, and under the ordinary conditions of marketing they do not cause much economic loss by spoilage and are not of importance to the public health. Scrupulous cleanliness at all stages is, however, essential for the production of milk of this standard of bacterial purity. The cow-shed must be light and airy, clean and free from litter, dust, mud, and—as far as possible—dung, and it must be well drained. The cows must be kept clean and well groomed, so that their coats are free from earth, mud, and manurial soiling at the time of milking and there are no loose hairs to fall off into the milking-vessels. The hands, person, and clothing of all persons handling the milk at any stage

on its journey from the cow to the consumer must be kept scrupulously clean, and no human carrier of pathogenic bacteria must be allowed to handle the milk. This high standard of cleanliness requires intelligent and willing co-operation between the farmer, the milker, the wholesaler, and the retailer. It also costs money, and the farmer who produces clean, rich milk should be adequately recompensed for the care and expense he must give to its production and officially encouraged to continue his good work. Under existing conditions in this country he is more likely to be penalized!

Cow-dung contains more than 1 million germs per gramme weight, and the straw, earth, and litter that are present in the dirty cowshed may contain up to 20 million germs per gramme. The dust that may be stirred up from this litter is therefore heavily contaminated with undesirable bacteria. It is inevitably stirred up by the movements and operations of milking, and the milk is bound to be contaminated to some extent by the aerial dispersal of the dust. Cows are prone to soil their hides with mud and manure which rapidly dry and powder, and if this dirt is not carefully washed off the animal's hide before milking is begun, the milk will be heavily contaminated. Dirty milk, collected under unsatisfactory conditions, may contain many millions of germs per cubic centimetre. Such milk is unfit for human consumption, even though it may not contain any human pathogens, and it is uneconomic because its market life is greatly reduced by the destructive activities of the contaminating germs.

The common contaminants of cow's milk are (*a*) types of cocci, especially streptococci, and (*b*) bacilli of the Coli-Aerogenes group. They are present in cow-dung and, as they are hardy germs, in manurial dust. They are able to ferment the natural milk-sugar, lactose, with the production of acid which results in the souring of the milk and ultimately in its clotting. Their activities lead to the production of unpalatable flavours and objectionable odours, and consequently to much economic loss. Clean milk will keep for several days in cool weather, but dirty milk may be unsaleable after twenty-four hours. Normally, all cow's milk undergoes souring in time owing to the production of lactic acid by the fermentative action of its normal bacterial population. It is the lactic acid that gives the pleasant, delicately acid flavour to the milk cheese that the knowing housewife makes from soured milk, but its presence in milk usually makes that drink unpalatable to most people.

The bacteria that are commonly responsible for the rapid spoilage of milk under ordinary marketing conditions are mostly non-pathogenic for man. The dangerous germs that cause specific human disease enter the milk either from endogenous or from exogenous sources. Endogenous sources include (*a*) infections of the udder and teats, and (*b*) generalized infections of the cow associated with the presence of germs in the animal's blood.

The most dangerous human pathogen that commonly enters cow's milk from endogenous sources is *B. tuberculosis*. It does not multiply in the drawn milk or in milk products under ordinary market conditions, but it is such a resistant germ that it remains alive and virulent in milk, cream, butter, and cheese for long periods. Raw milk is a less dangerous vehicle than raw cream and butter, because during the process of separation of the cream the bacillus tends to be concentrated in the fat fraction of the milk and pass over into the cream. Similarly, in cheese production most of the bacilli are precipitated with the milk-fat and are concentrated in the curd. Bovine tuberculosis is a disease of very serious economic importance to stock-breeders and dairy-farmers and is responsible for a large volume of human disease, especially among children. The cattle type of *B. tuberculosis* is responsible for about 6 per cent. of all deaths from human tuberculosis in England and Wales, and about 4,000 fresh cases of human infection occur each year. The proportion of tuberculosis cows in our milch herds varies in different districts, but in some it may be as high as 40 per cent. The proportion of raw milk containing living *B. tuberculosis* also varies in different parts of the country, but it has been authoritatively estimated that from 7 to 10 per cent. of the total raw milk supply of England is infected.

B. tuberculosis can be killed by a degree of heat that will not destroy the food value of cow's milk for man, although some people do not like the flavour of heated milk. Raw milk can be obtained free from *B. tuberculosis*, and such milk, certified to be free, is sold in this country under the designation of Tuberculin Tested milk. The production of this milk costs the farmer much more than the production of ordinary, ungraded milk, and he is therefore entitled to charge more for the product. The extra cost is, however, a wise economy when it is a case of feeding raw milk to infants, young children, and invalids. Unfortunately, the present official attitude in this country appears

to be one of active discouragement of the production of Tuberculin Tested milk in favour of the pasteurization of all milk supplies.

Other human pathogens that may enter cow's milk from endogenous sources are *Br. abortus*, the causal agent of undulant fever, and the bacilli of the Salmonella group responsible for bacterial food poisoning in man. Both these diseases have been described in earlier chapters.

Bacteria contaminating milk from exogenous sources may be derived from:—

1. The hide of the cow, usually as a result of soil and dung contamination;
2. Dust, straw, and litter in the cowshed, usually as a result of aerial dispersal;
3. The vessels used for collection and storage;
4. The hands, person, and clothes of the milkers and distributors;
5. Flies, other insects, and vermin gaining access to the milk;
6. Contaminated water used for washing utensils, equipment, and for cooling purposes.

Many dangerous human pathogens may be introduced into milk from sources outside the body of the cow, in fact any germ that causes human disease may gain entrance by droplet contamination from, or handling by, a human carrier. Delicate obligate tissue parasites such as the meningococcus, gonococcus, and *Treponema pallidum* die out so rapidly at room temperature that their presence in milk is not of importance. Moreover, none of these germs can enter the human body by way of the alimentary tract. It is the germs that enter by that portal, or are able to establish themselves in the mouth, whose presence in raw milk constitutes a danger to individual and public health. The important human bacterial diseases that may be milk-borne are typhoid and paratyphoid fevers, bacillary dysentery, tuberculosis (human type), diphtheria, tonsillitis, bacterial food poisoning of the invasive kind, and cholera. The human carrier is the ultimate source of the contamination in all these milk-borne epidemics, but the contamination may not be direct. Most of these germs are capable of survival outside the human body in water and dust, and indirect contamination may therefore occur when the milk is stored or distributed under unsatisfactory conditions. For example, a consumptive person employed on a farm, or in a dairy, who is expectorating *B.*

tuberculosis in his sputum, may contaminate the floor and walls of the cowshed, or the dairy, the milking-pails and utensils, and even the cows' hides. After his sputum has dried to dust, heavy wind-blown contamination of exposed batches of milk may easily occur. In the case of the human type of *B. tuberculosis*, however, contamination of milk more often results from its handling by a person suffering from tuberculosis of the lungs, genito-urinary tract, alimentary tract, or skin.

B. typhosus is able to multiply in milk without causing any detectable change in it, and multiplication may be rapid at summer temperatures. The germ may enter the milk in a variety of ways. Direct contamination may result from the handling of the milk by a human carrier, or by an "ambulant" case of the disease. Indirect contamination of the milk may result from its contact with (*a*) the dried fæcal matter from a typhoid patient; (*b*) flies that have fed on typhoid fæces; (*c*) empty milk-bottles from a typhoid sick-room that have not been sterilized; (*d*) sewage-polluted water used for rinsing the dairy utensils, and (*e*) shed hairs and dried earth and mud from the hides of cows that have been in contact with sewage-polluted water. The last two sources are the ones that are most likely to cause widespread milk-borne epidemics, because they alone permit of a sufficiently heavy and continuous contamination of the milk. The human carrier always excretes the germ intermittently; wind-blown dust contamination is likely to be intermittent and uneven, and flies can only transmit a limited number of the germs. The danger of indirect contamination from sewage polluted water is greatest on farms that draw their water supply for dairy purposes from a defective shallow well, or from an untreated stream, or where the cattle are allowed to wade in a pond or a stream. As I stated in the previous chapter, no surface water anywhere in England is certainly safe from sewage pollution, and unless the water in the stream or pond is controlled by regular bacteriological analyses, an unjustifiable risk is taken in allowing it to be used by milch cattle. *B. typhosus* can remain alive for at least 6 weeks in milk kept in the refrigerator and for more than 6 months in milk kept at room temperature under laboratory conditions. It can remain alive for at least 5 months in butter kept under ordinary market conditions and for 2 years in ice-cream kept in a frozen state. Milk, butter, cheese, and ice-cream may therefore all be vehicles for the spread of typhoid fever.

In addition to the diseases already listed, there is another group of ill-defined disorders of the human alimentary tract that may be milk-borne, and that are of great importance to the public health because of their selective incidence in infants and invalids. This group includes the diseases known to the medical profession as infantile diarrhœa, summer diarrhœa, and cholera infantum. No one germ has been proved to be responsible for these diseases, and it has been suggested that they are caused by the absorption of poisonous alterations in the milk resulting from bacterial activity, rather than by infections with living germs. There is little doubt that milk that is heavily contaminated with cow dung, cow hairs, blood, pus, and cow-shed dust is not suitable for human consumption; yet milk in this condition is marketed in this country. I have personally examined some deposits from market milk that contained all the above foreign matter, together with a correspondingly florid bacterial content. The mortality rate of these diseases is high under 1 year of age, especially among artificially-fed infants, who also show a much higher incidence of disease than breast-fed infants. There is a well-marked seasonal incidence in the summer months, when carrion flies are prevalent, and the incidence is higher in dusty urban areas than in rural districts. The seasonal and topographical incidence suggests that flies and wind-blown dust are important factors in the contamination of the milk and emphasizes the necessity for carefully screening all stored milk supplies in the home, the school, and the institution, that are to be fed to infants and invalids.

Some of our national milk supply is now pasteurized, and many authorities are convinced that universal pasteurization of all cow's milk intended for human consumption in Great Britain is an essential measure for safeguarding the public health. There are several different processes, but they all depend upon subjecting the raw milk to a temperature between 145° and 150° F. for 30 minutes and then cooling it rapidly to 55° F. or below. There is no doubt that efficient pasteurization destroys all the human pathogens, except bacterial spores, that may have entered the raw milk, and so protects the consumer from a formidable list of bacterial diseases. This protection depends, however, upon efficient pasteurization; inefficient pasteurization may be worse than the danger it sets out to abolish. The dangers of pasteurization are: (*a*) that the process is apt to engender a false sense of security, and (*b*) that it tends to en-

courage laziness and slovenliness in the collection of the milk. Pasteurization fails to achieve its object in the presence of milk that is heavily contaminated with foreign protein matter like cow dung, straw-dust, and pus. The heat coagulates these proteins, and the coagulated proteins form protective coverings around the bacterial cells, thus protecting the germs from destruction. I have had opportunities of examining raw milks before pasteurization, and the same milks afterwards from the same firm of pasteurizers, and in practically every instance the efficiency of the pasteurization varied with the content of dirt in the raw milk. The dirtier the milk, the more difficult it is to pasteurize; and the knowledge that the milk is going to be submitted to the "*magic and infallible*" process of pasteurization, encourages some individual producers to refrain from any attempt to produce clean raw milk. Pasteurization will be a national asset when the Government, and more especially the vested interests concerned, demand a high standard of cleanliness from the individual producer and enforce that standard by frequent and regular examinations of the raw milk. At present no attention is paid to the quality of the raw milk before pasteurization, and our official standards of bacterial purity for pasteurized milk would be dismissed with contempt in any country with an intelligent national appreciation of the supreme value of pure milk as a staple food for man.

The present arrangement for the pasteurization of our milk supplies appears to be that each producer collects his milk in any manner he considers economical, and empties it into churns. Some of the churns are sterile, some are merely clean, others are frankly dirty. The churns are then dumped by the roadside, sometimes on wooden platforms, sometimes on the grass verge, or on railway-station platforms. Many readers must have seen some of these dumps when motoring through the country. As a rule, no attempt is made to shield the churns from the heat of the sun, and the covers may be dust-proof or they may not. Warmth increases the speed of bacterial multiplication and speeds up bacterial activities, and a churn of milk that has been warmed by the sun for an hour or two makes an excellent culture medium for many germs. At intervals large tank-lorries come along, and the churns are emptied into the tank. When the tank is full, each lorry proceeds to the pasteurizing depot, where the mixed milk is pasteurized and then bottled for distribution. As far as I am aware, no attempt is made to grade the raw milk

before it is collected in the tanks; good, bad, and indifferent supplies are all emptied into the same tank. The official attitude appears to be that as the milk is going to be subjected to the *magic* process of pasteurization, there is no need to worry about dirt and pus in the raw material. Yet I have frequently examined samples of pasteurized milk that were quite unfit for human consumption in my opinion, although they conformed to the present official standards of bacterial purity. There is no excuse for dirty pasteurized milk, and the responsibility for ensuring that only clean milk is pasteurized must fall upon those who support the process either from hygienic or from financial motives. It is questionable whether dirty milk that has been effectively pasteurized, in the sense that the bulk of its bacterial population has been destroyed, can be regarded as a suitable human food. We do not know what poisonous products are formed by heating cow dung, byre dirt, and pus to the temperature of pasteurization; but few people would willingly drink a dilute emulsion of cow dung even after pasteurization, and there ought not to be any cow dung in the bulk supplies of raw milk that are pasteurized in this country today.

The first step in the efficient pasteurization of our national milk supplies should be to insist upon, and enforce, a high standard of cleanliness on the part of the individual producer, and the removal of all diseased cows from any milch herd. A cow will continue to yield milk even in an advanced state of disease, and there is a tendency on the part of some producers to retain an animal in the milch herd as long as it will yield milk. The producer is no more to blame than the system under which he is at present obliged to work. The loss of a milch cow is a serious matter for the small producer, and the compensation he receives for the official destruction of a diseased animal is inadequate. The churns, collecting-tanks, and pasteurizing plants should be sterilized at frequent and regular intervals. Mere cleaning is not a sufficient protection. Bacterial spores can withstand pasteurization, and these may collect in dirty, contaminated receptacles. Bacteria that are trapped in thin films of coagulated milk protein under the rims of churns, around the inlet and outlet pipe flanges of collecting-tanks, at the junctions of pipes on the pasteurizing plant, and in the blind ends of the piping, are protected from disinfectants and from the degree of heat employed in pasteurizing. These films require to be scraped away periodically and the receptacles and piping

subjected to high-pressure steam treatment, otherwise the raw milk may be so heavily contaminated that pasteurization fails in its object, or the cooled milk after treatment becomes heavily contaminated. The bottles must be sterile prior to filling, and the filling must be performed in a dust-free atmosphere and under conditions of scrupulous cleanliness and antisepsis. Finally, no human carrier of the human intestinal pathogens, or of *B. tuberculosis*, should be allowed to work in any capacity in the Dairy Industry.

Pasteurization does not aim at sterilizing the milk, but at destroying its content of dangerous germs. Heat-resistant germs, belonging to the group of the saprophytic Thermophilic Bacteria, are normally present in cow's milk, and these germs will withstand much higher temperatures than those employed in pasteurization. The important fact remains, however, that the dangerous germs that may be present in cow's milk will not be certainly destroyed unless the pasteurization is efficient and is performed on clean milk of good quality. Pasteurized milk is quite as susceptible to bacterial contamination as raw milk. Indeed, in some respects it is a more dangerous vehicle than raw milk, because the heat inhibition and destruction of the original bacterial population of the raw milk remove any chance of a competitive struggle between the immigrant pathogen and the original population. As I have mentioned in a previous chapter, pathogenic germs entering the natural cavities and ducts of the human body have to establish themselves in the face of competition with the obligate tissue saprophytes and commensals that are in possession and have adapted themselves to their environment. The same is true to a lesser extent of pathogenic germs that find their way into raw milk, and the real danger of pasteurization is that the milk may be contaminated after treatment in the depot, the retail shop, or the home. All pasteurized milk should therefore be sold only in air-tight bottles or cartons, and no one should be allowed to sell it in bulk, or to break the seal of a bottle or carton before delivery to the consumer.

CHAPTER XIX

ALLERGY

ALLERGY is defined as a state of altered reactivity on the part of the body tissues of man and animals. Under certain conditions, the tissues may become abnormally sensitive to substances and agencies that do not excite any reaction on the part of normal tissues. Examples of this state of hypersensitivity in man will be familiar to the reader under the names of hay fever, asthma, migraine, prurigo, and urticaria. The sufferer from hay fever is abnormally sensitive to some agency that is present at times in the atmosphere we breathe, usually the pollens of certain related plants. The normal individual can breathe an atmosphere heavily charged with these microscopic pollen-grains without feeling any discomfort; but when the grains come into contact with the nasal membrane of the unfortunate hypersensitive individual a violent, abnormal reaction takes place in his tissues and is manifested by the clinical state of hay fever. This hypersensitive, or allergic, state is a specific state. The hay-fever patient is not hypersensitive to all plant pollens; his sensitivity is specific to the pollen of a particular species of plant, although the pollens of closely related species may precipitate an allergic reaction after the hypersensitive state has been established. The asthmatic person may be hypersensitive to plant, or animal, tissues and products, or to inanimate physical agencies, but his sensitivity is as specific as that of the hay-fever patient.

Allergy, then, is a state of exaggerated sensitivity to some substance that is foreign to the human body, but is harmless to the normal individual, or to some physical agency that does not affect the normal individual. It is not a disease, but an exaggerated reaction, a distinction that must be carefully borne in mind, because allergy may be associated with disease and may, in some instances, be the principal factor in the symptomatology and progress of a disease. The allergic individual can lead a healthy and active life in the intervals between his allergic attacks, and he can acquire immunity to, and resistance against, many bacterial diseases with the same ease and efficiency as the normal individual.

The tissue reaction that is evoked is always of the same kind in the same person, though it may vary widely in degree according

to the strength of the stimulus and the duration of its application. For example, the sufferer from urticaria may be hypersensitive to oysters, strawberries, and cinnamon, three different chemical compounds, but his tissue reaction will be similar in kind by whichever of these agents it is evoked. The reaction is evoked by contact with minute quantities of the agent and is quite distinct from any inherent poisonous quality that the agent may possess. For example, a person may be allergic to the flesh of the mussel and develop a violent urticarial reaction, or an asthmatic attack, after eating a minute quantity of the fish. The mussel can be a deadly poison for man under certain conditions, and if an allergic person were to eat the fish in its poisonous state he would show two distinct reactions, the one being the specific reaction of his hypersensitive tissues to the flesh of the fish, and the other being the reaction of his body to the mussel poison.

The particular substance, or agency, that is responsible for the allergic state is known as the allergen. The reader will remember that every species of bacterium has its specific antigen, and that when bacterial antigens are implanted in the tissues of the human body they stimulate the tissues to make specific antibodies. A similar process takes place in allergy; the introduction of the allergen stimulates the tissues to make a specific antibody, the allergin. Here, however, the similarity between the immune and the allergic state stops because, whereas the specific bacterial antibody is absorbed by the tissue cells and generally protects them against the homologous antigen, the allergin sensitizes the cells after its absorption so that they react in an abnormal fashion when the allergen comes into contact with them. Nevertheless, the allergin is a specific antibody and can react directly with the allergen to form a neutral, inert compound. The reasons why the same germ may evoke a state of immunity in one person and a state of allergy in another are: (*a*) that germs contain foreign proteins, some of which can possibly act as antigens and/or allergens, and (*b*) that no two individuals react in identical fashion to the same germ.

It is obvious that an allergen can only reach the cells in the internal tissues of the body, in which the allergic reaction usually takes place, by way of the blood-stream after absorption from one of the tracts of the body. If an individual has a sufficient excess of specific allergin in his body to allow of its presence in adequate quantity in his circulating blood, after his tissue-cells have absorbed their share, he will not show any allergic

reactions because the circulating allergin will neutralize the allergen before it can make contact with his sensitized tissue-cells. Here we have a state analogous to the state of humoral immunity that is present in the individual who has been naturally or artificially immunized with diphtheria toxin. The specific antitoxin circulating in the blood-stream neutralizes any future toxin that may be absorbed into the circulation. Many "normal" persons are not allergic because their tissues have made a sufficient quantity of allergin. The individual who does not possess a sufficient quantity of allergin is deprived of the barrier action that its presence in the circulating blood ensures. Consequently, the allergen is able to reach his sensitized tissue-cells, and it is the violent reaction between it and the allergin within the cells that evokes the allergic reaction. This intra-cellular reaction deranges the functions of the cells and alters their chemical constitution, and it is the poisonous substances liberated from the damaged cells that are actually responsible for the manifestations of the allergic reaction.

The allergic state may arise spontaneously, or it may be induced, and the allergen may enter the body by inhalation, ingestion, injection, or by contact with the skin. The plant pollens and the spores of moulds and other fungi, that are commonly present in the atmosphere during certain seasons of the year, are examples of allergens that enter the body by way of the respiratory tract. Some volatile plant and animal emanations also enter by that route. The foods that we eat and some of the drugs that we take, either under medical advice or of our own choice, afford examples of allergens that enter by way of the alimentary tract. Medicaments of all kinds constitute the source of the allergens that are injected into the body. The physical agencies of light, heat, and cold, certain plant and animal hairs and secretions, and some chemical compounds, afford examples of allergens that act through the skin. Bacterial allergens may enter by any of these portals, or by all.

Heredity plays a very important part in the development of the allergic state. Between 50 and 70 per cent. of all allergic persons have a family history of allergy, *i.e.*, some other member, or members, of the family in the preceding generation were allergic. The familial allergic state need not necessarily be inherited in the direct line; but, if the parents show no evidence of allergy, the state will be manifested by blood relations in the collateral branches of the family. Even when the inheritance

is direct, the condition shows itself in different guises in different members of the family. One of the grandparents, for example, may be an asthmatic. In the next generation one child may suffer from migraine, another from urticaria, or hay fever, while the rest escape. In the third generation asthma may reappear and other allergic manifestations are shown by members of the family.

The allergic state may arise as a congenitally acquired condition, and it may be either actively or passively acquired. The fœtus in the mother's womb may be actively sensitized by allergens circulating in the maternal blood in the absence of any evidence of allergy in the mother herself. The fœtus may also be passively sensitized by the passage of allergins in the maternal blood through the placenta. The newly-born infant may be sensitized by the absorption of allergens in the mother's milk, or, if it is artificially fed, in cow's milk. There is a widespread belief that prospective mothers should refrain from eating certain foods during pregnancy—the onion in any form is often taboo—and there is little doubt that there is a rational foundation for the exercise of care in the choice of diet during pregnancy. It is, however, very difficult to single out any one particular article of food for incrimination, because the precise reaction to any particular food varies with the individual. After infancy, allergy may be acquired naturally through contact with some particular allergen, or the state may apparently develop spontaneously as a result of circumstances about which we have no knowledge. Food allergy is commoner in children than in adults and tends to decrease with advancing age, whereas inhalation allergy shows the reverse tendency. Skin allergy is often, but not invariably, an occupational affection, as shown by baker's dermatitis, fur dermatitis among furriers and sometimes among the feminine wearers of the finished product, and bulb dermatitis among bulb-growers and packers.

The allergic state commonly arises in infancy and childhood and tends to diminish with increasing age, as a result of a natural process of gradual loss of the specific hypersensitivity. Hay fever is, however, an exception to this general rule. The allergic state often shows a seasonal periodicity, which is especially evident in hay fever, and it is generally aggravated at night, especially in asthma. Most allergic states in women are aggravated at the monthly periods; but during pregnancy, and after surgical operations of any kind, they often dis-

appear for a variable period of time. They are often relieved by a change of residence, even though the climatic and topographical features of the new locality are similar to those of the old, and a sojourn in hospital for any reason generally relieves the state at once in the absence of any treatment. The allergic state appears to be linked up with the mental attitude of the individual, and there seems to be a psychological factor operating in many cases of allergy, although the individual may not be conscious of it. The repetition of the allergic attacks, which are usually heralded by subjective phenomena, produces an unconscious, or subconscious, mental state of a defensive nature, and the rapid alleviation that results from the admission of the individual into any hospital is possibly due to a psychological change from a subconscious mental state of fear to one of confidence.

Human bacterial disease may either induce or precipitate a latent state of allergy. Many allergic states manifest themselves for the first time immediately after some infection of the alimentary, respiratory, or genito-urinary tracts, as a result of the disturbances of function and the alteration in structure caused by the infection. The presence of a localized focus of sepsis anywhere in the body is a most important activator of allergy. Some bacterial diseases are particularly associated with the production of a specific allergic state, and their progress and manifestations may depend largely upon the presence and maintenance of such a state. The best example is that of tuberculosis. The body of the tubercle bacillus contains foreign proteins that act as allergens when they are introduced into the tissues of the human body. Only a minute amount of allergen is needed to sensitize the individual and, once the hypersensitive state has developed, only a minute amount is required to precipitate the allergic reaction. *B. tuberculosis* is so widespread among the population of the British Isles that most Britons are infected with it in childhood. If the infecting dose of bacilli is large enough to provide the requisite stimulus, or the reaction of the person's tissues is sufficiently active, enough specific allergin is made to provide a barrier of free allergin in the individual's circulating blood. If, on the contrary, the individual's production of specific allergin is insufficient to provide this barrier, he is left in a hypersensitive state, with a quiescent focus of living tubercle bacilli in his body. If he now comes into contact with a small dose of *B. tuberculosis*,

or with a minute quantity of tuberculous allergen, an acute allergic reaction occurs in his tissues, especially in those surrounding the quiescent focus, with the result that the focus flares up, a rapid multiplication of the germs takes place, and they spread into the surrounding hypersensitive tissues, increasing still further the individual's specific allergic state.

There is a growing belief among medical men to-day that the various human disorders grouped under the title of "rheumatism" are allergic manifestations of a specific individual hypersensitiveness to certain bacterial allergens. We are not yet sure which species of germ is responsible, but the weight of evidence that has been accumulated up to the present suggests that it is the Streptococcus, and probably the same kind of streptococcus that is responsible for tonsillitis and puerperal fever. The reader may find it hard to believe that the same germ can cause tonsillitis in one person, puerperal fever in another, a localized skin abscess in another, an allergic state manifested by rheumatic trouble in another, and a rapidly fatal septicæmia in another. He will probably find it still harder to believe that the same germ can cause all these different diseases in the same individual at different times.

The gardener knows that the way in which any particular plant develops in any particular garden depends upon the nature and composition of the soil, the care with which the soil is tended and kept free from weeds, the amount of sunshine and fresh air the plant obtains, the extent to which it is shielded from cold, damp, and frost, and the amount of warm, clean rain-water it receives. The development of identical plants may differ widely in different gardens, sometimes so as to be unrecognizable as the same kind of plant. What is true of a plant in the garden is also true of a germ in the human body—its development is determined by the nature of the soil and environment in the individual host, and, at the same time, the reaction of the host is also determined by the nature of the soil. The manifestations of disease that may result from the establishment of any pathogenic germ in the human body are therefore determined in general by the biological characters of the germ, its virulence and dosage at the time of infection, its portal of entry to the body, and the inherent capacity of the tissues of the human species to react to its attack. The precise manifestations of disease that may result from the establishment of the same germ in the body of a particular human being are

determined by the particular state of health and reaction of the individual, *i.e.*, the particular soil and environment, at the time of its attack. No two human bodies react in exactly the same way to the same germ, and no germ ever invades two human bodies under identical conditions of dosage and virulence. One person may overcome the infection and acquire either immunity, or a high degree of resistance, to the germ; another may overcome the infection, but be left in a hypersensitive state. A germ that has a predilection for a particular tissue of the human body, or for a particular portal of entry, will produce its specific disease only when it is implanted in the tissue, or enters by the proper portal. When it is implanted in some other tissue, or enters by some other portal, it may induce a state of hypersensitivity instead of a clinically recognizable attack of a specific disease. The decisive factor is that bacterial bodies contain foreign proteins that can function as antigens and/or allergens according to the conditions under which the germ enters the human body and is received by the tissues of the individual host.

Scarlet fever has been mentioned, and I have stated that there are two factors operating to produce the clinical picture of the disease: (*a*) a streptococcal invasion of the tonsil, or the adjacent regions of the throat, and (*b*) the absorption of a diffusible product made by the germ that is responsible for the rash, the fever, and the other features of the disease. I have previously spoken of this product as a bacterial exotoxin because it is poisonous for man, but recent investigations strongly suggest that its primary function is that of an allergen. Let us therefore reconsider the problem of scarlet fever from the standpoint of its acceptance as an allergic disease. John Bull, with whom the reader is already acquainted, contracts a streptococcal infection of his throat from one of his schoolmates as a result of droplet spread. Some of the possible results of this infection can be best expressed in tabular form.

A. The dose of streptococcus is large, the virulence of the germ is high, and John's resistance is low at the time of his infection.

1. He develops a severe tonsillitis, in which the invasive power of the streptococcus predominates over its power to form its diffusible product.

(*a*) He may die from a septicæmia.

(*b*) He may suffer from an extension of the infection to his middle ear, lungs, or other organs of the body.

(*c*) He may recover (i) completely and acquire an immunity against the toxic fraction of the diffusible product, or (ii) be left in a hypersensitive state.

2. He develops a severe tonsillitis, in which the toxic power of the streptococcus predominates over its invasive power.

(*a*) He may die from the damage wrought on his heart or his kidneys by the toxin.

(*b*) He may recover completely and acquire an immunity to the toxin.

(*c*) He may recover, but be left in a hypersensitive state, although this is unlikely if there was a large production of the diffusible streptococcal product.

B. The dose of the streptococcus is low, its virulence is low, and John's resistance is low at the time of his infection.

1. He develops a moderately severe tonsillitis, in which the invasive power of the streptococcus predominates over its toxic power.

(*a*) He may suffer from a chronic tonsillar inflammation, or from an invasion of the adjacent cellular tissues (cellulitis), or from abscess formation in the lymphatic glands that drain his tonsillar region.

(*b*) He may recover completely with (i) a degree of acquired resistance, or (ii) with a residual hypersensitive state.

2. He develops a moderately severe tonsillitis, in which the toxic power of the streptococcus predominates over its invasive power.

(*a*) He may suffer from a chronic, low-grade toxæmia that undermines his general and local resistance.

(*b*) He may recover completely with a partial immunity to the toxic fraction of the diffusible product.

C. The dose of streptococcus is large, its virulence high, and John's resistance is high at the time of his infection.

1. He develops a sharp attack of tonsillitis, in which the

invasive power of the streptococcus predominates over its toxic power.

(*a*) He may develop a localized abscess in one or both tonsils, or a swelling of the regional lymphatic glands that does not progress to abscess formation.

(*b*) He may recover from the infection completely, or recover from the invasion but be left in a hypersensitive state to the diffusible product.

2. He develops a sharp attack of tonsillitis, in which the toxic power of the streptococcus predominates over its invasive power.

(*a*) He may suffer from a temporary disturbance of the function of his heart, or his kidneys, which subsides without any permanent disability.

(*b*) He may recover completely and acquire a solid immunity to the toxic fraction of the diffusible product.

D. The dose of streptococcus is small, its virulence low, and John's resistance is high at the time of his infection.

He has a slight, transient attack of tonsillitis, with little or no constitutional disturbance, from which he recovers rapidly and completely with an increased resistance against both the germ and its diffusible product.

The above table by no means exhausts the possible results of John Bull's infection; but it shows, at least, that the interplay of any particular pathogenic germ and any particular human host is a most complex performance, and that it is often impossible for the doctor to foretell the end result. If John picks up another dose of the same streptococcus some months after his recovery from the above attack, his reaction to the second infection will be determined by the state in which his tissues were left after the first infection. If they are hypersensitive, he will develop the clinical picture of scarlet fever, or, possibly, of rheumatic fever, depending upon the nature and degree of his hypersensitivity and the biological state of the streptococcus at the time of the second infection. If his tissues are sensitized, but not hypersensitive, he may suffer from so-called "growing pains", which are childhood manifestations of rheumatism. If his tissues are resistant, he may again develop a sore throat, but he will recover from it rapidly and will not exhibit any constitutional disturbance. Scarlet fever is most probably a

combination of tonsillitis plus toxæmia plus allergy. Very many children and young adults suffer from multiple attacks of tonsillitis, but only a small proportion of them show the clinical picture of scarlet fever. The scarlatinal victims are the unfortunates who have acquired the additional factor of allergy. Any subsequent allergic reactions that John Bull shows towards his streptococcal throat infections are determined by (*a*) the dose of streptococcal allergen, (*b*) the rate at which it is absorbed by his tissues, and (*c*) the reactive capacity of his tissues.

Hypersensitive individuals can be desensitized, either naturally or by artificial means. Repeated natural contacts with the allergen tend to desensitize, and these contacts explain why many allergic conditions that take origin in childhood tend to disappear with advancing age. The difficulty experienced in artificial desensitization is to find the allergen that is responsible for the condition. The person who suffers from hay fever is sensitive to only a few of the hundreds of plant pollens that he may inhale during the spring and summer months. His sensitivity can be tested by injecting minute amounts of pollen extracts into his skin, but it is not possible to test every pollen, or even every group of closely related pollens, in this way. Moreover, in some cases at least, the increased actinic power of the light during the spring and summer months appears to be an activating factor, and we cannot desensitize a person against light. The asthmatic may be hypersensitive to bacterial allergens, mould spores, horse-dander and horse-hair, cat hairs, the emanations from animals and plants, or other agencies, and it is often impossible to discover the allergen that is responsible for the individual state. Once the allergen is discovered, the individual can be desensitized by a carefully graded series of injections of an extract, emulsion, or suspension, providing that the allergen is a substance that can be obtained in one of these forms.

Allergy is rarely immediately dangerous to life; but repeated attacks tend to lower the resistance of the individual to other diseases and, in the case of asthma particularly, to result in structural changes in the hypersensitive tissues that reduce their local resistance and impair their function. There is another sensitive state, fortunately very rarely found in man under natural conditions, which may be fatal. This state is known as anaphylaxis (pronounced anna-fillaxis). It may be defined as a greatly increased sensitiveness of the body to the presence in

the tissues of an antigen, so that the introduction of the antigen in amounts innocuous to normal individuals of the same species produces in the hypersensitive animal symptoms of varying intensity, and even acute death. The first, or sensitizing, dose of the antigen need only be small, and the more inherently poisonous the antigen, the smaller is the dose required to sensitize. An interval of at least 10 days must elapse after this dose before the individual is sensitized. The activating dose of the antigen must be relatively large, at least 100 times greater than the sensitizing dose. The anaphylactic state that develops under these conditions is as specific as the immune state, and the manifestations of the state are constant for each animal species, irrespective of the nature of the responsible antigen, although they differ widely in the different animal species.

It is believed that the weak primary stimulus provided by the small initial dose of antigen evokes only a feeble production of the specific antibody, which reaches its maximum production in about 10 days. This small quantity of antibody is absorbed by the tissue cells, so that there is no surplus to circulate free in the blood. If a large dose of the homologous antigen now enters the circulation, it enters into a violent chemical reaction with the antibody in the tissue-cells, thus causing a grave disturbance of their functions. If, however, there is sufficient free antibody circulating in the blood to neutralize the antigen before it can reach the tissue-cells, as there is in the immune state, no anaphylactic reaction can occur. Anaphylaxis may therefore be regarded as the half-way house to the immune state. The anaphylactic individual can be desensitized by repeated injections of doses of the antigen that are too small to cause shock. Moreover, if the individual is given an injection of a fairly large dose of the antigen during the sensitizing interval —*i.e.*, the 10-day interval—he will not develop the sensitivity.

The only danger of anaphylaxis occurring in man, and it is a remote one, is in connexion with the anti-serum treatment of bacterial diseases. In the early days of serum treatment, when crude sera containing much foreign animal protein were used, a few cases of anaphylactic shock in man were recorded. With the modern purified and concentrated anti-sera, anaphylaxis in man is extremely rare. Nevertheless, there is no reason why any individual should be exposed to the risk of it, because individuals can be tested for their sensitivity before they are given serum treatment. Such a test should always be performed on

any person who (*a*) has a personal history of allergy; (*b*) gives a family history of allergy, or (*c*) has had a single injection of some anti-serum within the preceding three months. A hypothetical illustration will perhaps make the position clear. The reader will remember that Mrs. Bull contracted diphtheria through nursing her little daughter. Her doctor wisely gave her several large doses of diphtheria anti-toxic serum; but if he had only given her a single small dose, she might possibly have developed anaphylactic hypersensitivity after a lapse of 10 days, because the blood serum of the horse contains proteins that are foreign to the human body and act as antigens when they are injected into human tissues. Let us suppose that Mrs. Bull did not actually have diphtheria at that time, but an inflamed throat caused by some other germ. Her doctor might give her a small, prophylactic dose of diphtheria anti-serum, just to be on the safe side, while he was waiting for the bacteriologist's report on her throat swab. If that report came back negative, the proper thing to do would be to immunize Mrs. Bull actively against diphtheria by injections of the treated diphtheria toxin; because, once she was immunized, there would then be no risk that she might later contract diphtheria, after her single prophylactic dose of anti-serum, and require further serum treatment while she was in a hypersensitive state.

Most of the anti-sera that are used in the treatment of human bacterial diseases are made from the horse and, very rarely, an individual may need anti-serum treatment who has been rendered naturally hypersensitive to the antigens in horse serum by some previous contact with horses, or with products obtained from them—*e.g.*, cushions stuffed with horse-hair. Such cases are, however, so rare that the reader need not worry about them. I only mention them because there is no clue to the patient's state to warn the doctor that he or she is hypersensitive. About one person in every 70,000 treated persons develops some degree of anaphylactic shock after their first dose of anti-serum; but remedies are now available to treat the shock, and no one need be afraid of anti-serum treatment for the acute bacterial infections and toxæmias for which specific anti-sera are now available, because of the remote risk of anaphylactic shock.

CHAPTER XX

BACTERIAL WARFARE

UNDER ordinary conditions of warfare between nations, some of the human bacterial diseases normally tend to increase both among the combatant and the civilian populations. Wherever large numbers of men are crowded together under conditions of improvised sanitation and difficult personal hygiene the intestinal infections increase. Human carriers of *B. typhosus*, the paratyphoid bacilli, the dysentery bacilli, and the Salmonellas, are numerous in European armies, and carriers of *V. choleræ* are present in Asiatic armies. These carriers act as reservoirs for the spread of trench, camp, and barrack epidemics, and the risk of epidemic spread is increased when the troops remain more or less stationary for long periods. Modern trench warfare encourages the multiplication of vermin, especially rats, and these animals act as mechanical vectors of the human intestinal pathogens. The long spells of duty in the trenches (that may be necessary) without change of clothing and opportunities for bathing, encourage the multiplication and spread of human lice, and these ecto-parasites, in addition to their transmission of certain specific diseases, are the direct cause of much distress to sensitive individuals, and the indirect cause of septic conditions of the skin that lower the individual's resistance to other bacterial infections. The prevalence of punctured and badly lacerated wounds contaminated with soil and dirt increases the incidence of tetanus and gas gangrene. The enforced, unnatural sexual continence, and the complementary increased sexual licence, that are invariable concomitants of the dangers and strain of war, result in an increase in the venereal diseases, both among the combatant and the civilian populations. Among the non-combatant population in the war zone the strain of war, with its interruption of the normal mode of living, its resultant increase in the cost of living, and its reduction of the normal food supply, lowers the resistance of the population, especially of the children and the aged, to bacterial diseases.

Modern aerial warfare has greatly increased the strain upon the civilian populations of warring countries, and directly and indirectly seriously threatens the life and health of those populations. The aerial bombardment of cities and towns interferes gravely with the effective discharge of the essential services

upon which the health of their populations depends and aggravates the risk of epidemic disease among them. The rupture of sewers and water-mains by high-explosive bombs, the decomposition of fragments of dismembered human and animal bodies, and the enforced crowding together of people in air-raid shelters, are factors that are directly responsible for the dissemination of human bacterial diseases. The concentration of children in schools and improvised hostels away from the main centres of air attack—a wise and humane precaution—and the concentration of young adults in military training camps, increase the risk of outbreaks of "spotted fever". Exposure to inclement weather conditions as a result of the destruction of dwelling-houses and the enforced sheltering in cold, damp cellars and dug-outs, especially at night during the autumn and winter months, greatly increases the incidence of infections of the upper respiratory tract, especially of pneumonia. The wounds caused by splinters of glass, metal, and masonry travelling at high velocities and often contaminated with road dust, house dust, or fragments of clothing, result in a great increase in civilian tetanus and gas gangrene.

All these increases in the incidence of human bacterial diseases are, however, accidental to modern warfare and may be regarded as normal concomitants of warfare between "civilized" peoples under present conditions. The phrase, "bacterial warfare", does not refer to this accidental increase. It implies, on the contrary, a deliberate and systematic attempt on the part of an enemy to introduce and disseminate certain bacterial diseases of man among the opposing combatant, or civilian, populations, or both. The use of bacteria in human warfare is contrary to international law, and all the European nations have pledged themselves to abstain from it. No pledge, however, is likely to restrain an unscrupulous and unprincipled aggressor nation that is determined to inflict the maximum damage and suffering of which it is capable upon its opponents. The only deterrent to the use of pathogenic bacteria by such a nation is the fear that its violation of international law and its disregard of all humane principles may recoil on it, because bacterial warfare is a two-edged weapon, or that its opponents may be able to exact a more disastrous and effective retribution.

We can best approach the problems of bacterial warfare by asking ourselves (*a*) what are the objects of this form of warfare, (*b*) how can they be achieved, and (*c*) how can they be defeated.

It is generally accepted as an axiom in modern warfare that an enemy casualty is worth more than an enemy corpse. A dead person has gone beyond our recall and, as human grief is finite and human memory is short, the sorrow and distress over the death of a loved one in war-time are quickly blurred and softened by the necessity to devote care and attention to the protection of the living. The casualty, however, is not yet beyond our recall. Will he recover? If he recovers, will he be disabled or disfigured? How soon will he recover? Is he in pain? Would he like to see me? Can I do anything to help him to recover? Is he receiving proper nursing and medical attention? These and many other worries distract the thoughts of relatives and friends and interfere with the effective performance of their daily work and war-time duties. Moreover, the casualty requires medical and nursing attention, often costly transport over long distances, residence in hospital, nursing-home, or convalescent home for a variable period, often special food, and often operative treatment. All these requirements are costly and consume a large amount of the time and energy of a considerable proportion of the population. Every casualty therefore means a continuous drain upon the financial resources and the will to war of the enemy population.

The bacterial diseases of man are pre-eminently casualty diseases. Many of them have only a low mortality rate under modern conditions of treatment; but their morbidity and disability rates are often high, convalescence is often protracted, and each patient requires constant nursing attention and regular medical supervision. If the responsible bacterium is disseminated by both direct and indirect contact, costly quarantine measures may be necessary to prevent the disease from spreading, and the provision of expensive sterilizing equipment to deal with fomites may be required. If a widespread epidemic of one of these diseases could be deliberately started among an enemy population, the consequent dislocation of the national life and of the essential public health services might have a determining influence upon the course and result of a war.

It is not easy, however, to start an epidemic of human bacterial disease artificially. The choice of an agent is difficult, because many incalculable factors operate to determine the efficiency of each agent among a given population at a particular time. In order to provoke an epidemic, the agent must be virulent at the time of its deliberate dissemination, capable of a reasonable

survival time outside the human body, and possessing a high degree of infectivity. Contagious diseases that depend for their dissemination upon the transmission of the agent by direct personal contact only will not certainly produce the requisite result. The selected germ must be capable of transmission by both direct and indirect contact in order to ensure its epidemic spread. The choice of human pathogens possessing these properties is limited and, for practical purposes, is restricted to the intestinal pathogens (*B. typhosus*, the paratyphoid bacilli, the dysentery bacilli, and cholera), plague, and possibly anthrax.

After a suitable agent has been chosen, the problem of disseminating it effectively among an enemy population has to be solved, and the solution becomes increasingly difficult the more efficient are the sanitary intelligence, the personal and communal hygiene, and the medical services of that population. Moreover, Great Britain is an island state, and therefore direct transmission of the agent by contiguity across land frontiers is not possible in our case. The methods of dissemination of the agent available to an enemy attacking us are therefore restricted to (*a*) dissemination from the air by means of raiding aircraft, and (*b*) dissemination by human agents introduced into, or resident among, the population of these islands.

Air raids loom largely in the mind of the civilian in these days of modern aerial warfare and, if he is confronted with the possibility of bacterial warfare, he is naturally inclined to picture the dropping of multiple bombs filled with pathogenic bacteria from enemy aircraft. Let us therefore consider first this possibility. In order to fill a small bomb, or other suitable container, a huge number of germs must be collected as a dry mass in powder form, or in the form of a semi-solid emulsion, or as a dense suspension in a liquid medium. A sufficient number of germs could not be obtained directly from human, or natural, sources, so that recourse must be made to their multiplication by cultivation on artificial foodstuffs in a laboratory. A constant feature of the artificial cultivation of pathogenic bacteria is that all these germs gradually lose their virulence, and therefore their power to cause disease in man, under these conditions. As a general rule, the more deadly the germ, the more rapidly it loses virulence in artificial culture, although there are exceptions. Some of the obligate human pathogens lose their virulence very rapidly in artificial cultures and after a few generations are unable to infect man. Other germs that are

hardier and not so specifically parasitic lose their virulence more slowly; but all the human pathogens lose their virulence steadily in artificial culture, and this loss cannot easily be repaired. Bacterial spores retain their potentiality for germinating into virulent vegetative germs for long periods, but there is no multiplication of the bacterium through the spore stage, and the vegetative cells of the spore-forming bacteria lose their virulence steadily outside the human and/or animal body. The virulence of some human pathogens can be restored, and even increased, by passing them through a series of susceptible animals; but there is a maximum limit of virulence for each species of pathogen that can be obtained in this way, and further animal passage will not raise the virulence above this limit. The necessary animal passage is costly in time and money, and there is always the risk that the persons doing the work may become infected and transfer the infection to their fellows. In any case, the germ must be isolated again from the animals and grown in artificial culture before it can be filled into a bomb, and during this process there will be an incalculable loss of virulence. It is therefore very difficult to ensure that the germ bomb will contain bacteria of a sufficiently high degree of virulence to cause human disease when it is used. The enemy might drop the whole, or the minced, carcases of diseased animals from raiding aircraft, but the difficulty in this method is to ensure contact of the germ with human beings before the natural destructive agencies have destroyed the germ, or reduced its virulence.

When the bomb has been filled, there will be a steady loss of virulence and a gradual death of the germs, unless it is used immediately. Storage at room temperature for 24 hours will appreciably reduce its content of viable germs and diminish the virulence of the remainder. Storage at refrigeration temperature will prolong the life and preserve the virulence of the germs, but refrigerator space is limited and the plants are costly to instal. The heat set up by friction due to air resistance will also reduce the viability and virulence of the germs, if the bomb is released from any height above a few hundred feet. This might be overcome by insulating the bacteria inside the bomb, but the necessary insulation decreases the space available for the germs and increases the cost of the bomb. The heat and disturbance produced by the explosion of the bomb will also destroy some of the germs and reduce the virulence of others, even if only the minimum amount of explosive is used to shatter

the bomb case. The bomb could, of course, consist simply of a thin-walled glass or metal container that would burst open on contact with any hard surface, but the more delicate the container the greater will be the risk of handling it in filling, storage, and transport. The bomb must have a sufficiently tough casing to allow of its being handled with impunity by enemy personnel.

The bomb must land in some situation where the released germs are quickly brought into contact with susceptible human beings, otherwise the natural destructive agencies of light, cold, and drying will operate to destroy the germs or reduce their virulence. None of the human pathogens that could be used effectively by an enemy has an inexhaustible capacity for survival outside the human body. This means that the bomb must be dropped in crowded urban areas, or on schools, camps, hospitals, theatres, or other places where people congregate. Bombs dropped in the open country, in urban parks and open spaces, and even in wide roadways, would be largely innocuous because rain, or deliberate hosing, would rapidly wash the germs into the soil and into drains, where they would not come into contact with man and would be destroyed by their environment. Many very large bombs filled with highly virulent germs would be needed to contaminate the water in a reservoir of average size, and it is doubtful whether large volumes of water like Lake Vyrnwy could be effectively contaminated from the air. It would be easier and cheaper for the enemy to poison the water supply with some water-soluble chemical poison. On the whole, therefore, the chances of introducing and disseminating human bacterial diseases by bombing from the air are slight, and the uncertainty and expense of the method militate against its use.

Possibly a more effective method would be to spray a suspension of germs in a suitable liquid medium from low-flying aeroplanes over densely-populated areas; but this method has its disadvantages. The germs would need to be artificially cultivated in the laboratory and there would be a steady loss of virulence and death among them while they were in storage in the tank of the aeroplane. If they were sprayed from a height of more than a few hundred feet many of them would be killed, and the virulence of others reduced, by natural destructive agencies before their slow sedimentation by gravity brought them into contact with human beings. Moreover, slight winds in the upper atmosphere, and air currents nearer the ground might disperse them too widely to provide an individual infect-

ing dose. The expense and time required to prepare a sufficiently large volume of a thick suspension, or a heavy fluid culture, of germs that would be worth while transporting by aircraft over enemy territory would be considerable, and the inevitable loss in virulence of the germs during transport and sedimentation militates against the success of this method. Many would undoubtedly fall on the roofs of buildings and would be washed into the gutters, where they would perish, and many others would fall on road surfaces and be rapidly washed into the drains. Spraying a lethal gas like mustard gas in its liquid form would be cheaper and more effective, but this is generally considered to be a relatively ineffective method over urban areas because so much of the spray will be trapped and lost on the roofs of buildings. Bacterial spores are so much more resistant than the vegetative cells that their use in the form of a spray is practicable; but the spores are themselves non-pathogenic, and their ability to germinate into virulent vegetative cells depends upon a conjunction of factors over which the enemy could not exercise any control. Moreover, none of the human diseases caused by a spore-forming bacterium is infectious. Pulmonary anthrax, which may result from the inhalation of anthrax spores, is a deadly disease, but it is neither infectious nor contagious. Similarly, tetanus and gas gangrene are neither infectious nor contagious and, in any case, neither of these diseases is determined by the mere implantation of the spores on the surface of, or in the cavities of, the human body. Certain barbaric tribes still smear the heads of their war arrows with a paste containing the spores of tetanus, and some "civilized" peoples are quite capable of attempting to copy this example. The deliberate contamination of aerial bombs with the spores of *B. tetani* would, however, only increase the mortality rate among the civilian casualties caused by the bombs themselves; it would not cause an epidemic of bacterial disease among the uninjured population. Human bacterial diseases that depend upon the repeated contamination of an area with the responsible pathogens, or their spores, are neither economic nor practicable. The essential requisite for effective bacterial warfare is that the disease that is set up must be of such a kind that it will spread widely by natural means, after multiple foci have been established in the enemy population. It is doubtful whether the necessary epidemic spread could be achieved by the use of germs that have been artificially cultivated under

laboratory conditions and are then dropped, or sprayed, from aircraft. Theoretically, the method is feasible; in practice there are many difficulties and much uncertainty.

Human carriers of the different species of pathogenic bacteria are present in every country. Indeed, but for the presence of such carriers, many bacterial diseases of man would disappear with the destruction of the susceptible hosts. The causal agents of typhoid fever, bacillary dysentery, and cholera are excreted in the natural intestinal evacuations—and in the case of typhoid fever in the urine also—of human carriers, and there are no visible signs by which we can distinguish a carrier from a normal person. Moreover, the germs retain their virulence in the body of the carrier. The virulence may fluctuate slightly, but it is never lost. It is true that the carrier's excretion of his germ is always intermittent and that the numbers excreted very widely at different times, but we have proofs that many serious epidemics of typhoid fever, dysentery, and cholera have taken origin directly from human carriers. The recent epidemic of typhoid fever at Croydon is an example.

The deliberate dissemination of bacterial disease by enemy agents is undoubtedly a practicable proposition. It is a more effective method than dissemination from the air because (*a*) it avoids the danger, trouble, and expense of the artificial cultivation of the selected germ in a laboratory and its transport by aircraft over defended territory; (*b*) it provides a virulent germ, and (*c*) the opportunities for bringing the germ into intimate contact with the enemy population are more numerous, easier to obtain, and much more effective. For example, an enemy agent, who knew that he or she was a carrier of *B. typhosus*, could deliberately contaminate public water, milk, or food supplies without much difficulty, if he or she were sufficiently conversant with the language, customs, and manners of the people attacked to pass as a native of the country. Uncovered shallow wells in country districts and unguarded bulk supplies of unpasteurized milk almost ask to be contaminated in war-time. The contamination might be made to appear accidental, because a person who has been trained for such work could act by merely handling the milk, or food, with hands that were deliberately and regularly contaminated with fæcal matter and/or urine. As the carrier is immune to the germ he carries, this contamination of his hands would not expose him to infection. Water supplies that are efficiently chlorinated before

consumption will be safe against any deliberate contamination of the source. Pasteurized milk that is bottled at the depôt and sold in sealed bottles will also be safe, unless the agent is working as an employee of the pasteurizing concern and can gain access to the bulk milk after cooling and before bottling. The deliberate contamination of single bottles during the filling process is possible, but such contamination would be less likely to produce the requisite epidemic spread, and would probably result in the rapid detection of the agent. The unchlorinated water supplies of cities and towns that are supplied from large lakes, whether natural or artificial, will also be comparatively safe, because the enormous volume of water in such a supply would require a gross contamination much in excess of the capacity of a single human carrier. Repeated deliberate contamination at daily intervals would increase the danger of such contamination, but most of these lakes are patrolled in war-time, and any unauthorized person frequenting the vicinity of a lake would be detained for examination. The danger of the deliberate contamination of our water supplies is more or less limited to shallow well, spring, brook, and small reservoir supplies, *i.e.*, to small surface water supplies. Most of these supplies are situated in, and serve rural areas, where the machinations of an enemy agent are less easy to detect. The danger is increased in those districts that are housing abnormal war-time populations of school children that have been evacuated from our cities and towns. Typhoid fever is particularly a disease of late adolescence and early adult life; dysentery and cholera do not show such a well-marked age incidence, but the mortality rate for both these diseases is higher in childhood than in adult life. The danger of deliberate contamination of the water and/or the bulk milk supplies of war-time populations in semi-rural areas is a danger that must be faced during war against a barbaric and brutal enemy.

Deliberate contamination of a water or milk supply by a human carrier is not, however, quite as simple and effective in practice as it appears to be in theory. Every human carrier excretes the germ that he is harbouring intermittently, and the excretion is not associated with, or accompanied by, any warning symptoms or signs. He does not know himself when he is excreting the germ, and therefore, in order to ensure contamination, he must pollute the water, or milk, with his motions and/or his urine at regular intervals for a period of days or, possibly,

weeks. The constant presence of a stranger in the vicinity of a well, spring, reservoir, farm, or dairy, should arouse suspicion and lead the police to enquire into his activities. Moreover, when the carrier has contaminated the water, or milk, supply of a community, the ultimate fate of the germ is beyond his control. Under certain conditions it may die out, or lose virulence, so rapidly that it has ceased to be infective by the time the vehicle comes into contact with susceptible individuals. Climatic conditions often determine the survival time of *B. typhosus* in water and in milk, and the vagaries of the British climate are beyond human power to foretell with any degree of accuracy at present.

The defence of a population against bacterial warfare depends upon the effective co-ordination of (*a*) national measures, (*b*) local measures, and (*c*) individual measures. Ultimately, its success is determined by the degree of efficiency of its Health and Medical Services, and the average level of the sanitary intelligence, and the practice of hygiene among the common people. The wider and more accurate the knowledge about bacterial diseases in general that is possessed by the people, the less is the danger of bacterial warfare. This is one of the reasons for the writing of this book.

Every European country is now equipped with a number of bacteriological laboratories that are staffed with trained and competent bacteriologists, many of whom have also had a medical training, who have devoted their lives to the study of the bacterial diseases of man. Every country has also its national Health Service, with a centralized authority and localized services that cover every part of the country. Great Britain is particularly well-served in both these important respects. British bacteriologists are the equals of any among their continental neighbours, and we possess several specialists with international reputations who are in the forefront of their profession. The immediate mobilization of a country's resources in trained and experienced bacteriologists on the outbreak of war constitutes its first line of defence. Their investigations and discoveries can be communicated to, and co-ordinated by, the central authority of the national Health Service, which possesses the necessary organization and personnel to take prompt and effective action in any part of the country. The entire country is therefore kept under the alert watch of a corps of experts in the detection of human bacterial diseases. Under

such conditions, any deliberately induced, or natural, outbreak of bacterial disease should be discovered very quickly, and effective measures can then be taken to localize it and to protect the rest of the population against its spread. No bacterial disease of man is known that cannot be controlled by the prompt and proper application of modern measures of sanitation, quarantine, treatment, and artificial immunization of susceptibles, provided that the outbreak is discovered in its early stages. In this mobilization of the Nation's Bacteriological and Health Services we possess, therefore, a defence equivalent to our military Anti-Aircraft defence, and the people of Great Britain can rest assured that the one is probably quite as effective as the other.

The national defence service can be supplemented by, and strengthened by, the local Health and Sanitary Services acting under the co-ordinating authority of the central Health Service. In peace-time each Local Authority is responsible to the citizens living within its boundaries for the safety of their water, milk, and food supplies, and each has to shoulder a greatly increased responsibility in time of war. This essential work of the Local Authority can be seriously hampered by the opposition of ignorant, careless, selfish, and self-opinionated citizens; it can only be made effective by the loyal and continuous support of intelligent citizens. Many Local Authorities in peace time are inclined to risk the use of shallow well waters as public supplies without subjecting them to regular and frequent bacteriological analyses, because they fear the opposition of their rate-payers to the expense incurred in these analyses. The opposition is mainly founded upon ignorance; but there is no room for ignorance and no excuse for official temerity in time of war. An unscrupulous enemy is not likely to take notice of the opposition of enemy citizens to vital health measures, except to welcome it as a sign of the ignorance and unpreparedness of the population that is to be attacked. The supplies from shallow wells, springs, brooks, and small reservoirs, should be kept under continuous supervision in time of war. The Home Front is as vital to us as any Maginot Line, and the security of that front depends upon the health and welfare of the civilian population. Every collection of surface water that serves as a public, or private, supply must therefore be kept under constant supervision and controlled by regular bacteriological examinations at frequent intervals, and all defective, uncovered shallow

wells should be repaired and fitted with effective covers. Bulk supplies of unpasteurized milk should not be left unguarded, and care should be taken to see that all churns and tanks are provided with effective covers. These measures will cost money, but the British people are possessed of a sufficiently high average of natural intelligence to appreciate the need for this expenditure in their own interests, providing that the Authorities will take the public into their confidence and explain the reasons for the outlay.

Individual co-operation in the general scheme of defence against bacterial warfare is of vital importance to the success of the defence. The home and the family are the units on which this co-operation must be based. If the family can be protected and infection kept out of the home, there is little chance of any epidemic reaching serious proportions. All the intestinal pathogenic bacteria of man are easily destroyed by heat, and boiling the family drinking-water and milk supplies for a few minutes will make them safe, even though they were heavily contaminated. As soon as there is any evidence of intestinal infectious disease in the neighbourhood during war-time, this simple precaution should be taken by every household, without waiting for instructions from the Local Authority. In some cases the precaution will be taken too late, because the family will already have been unknowingly exposed to the risk of infection, but it will protect the majority of people in the district. Any case of diarrhœa should be reported to the family doctor, who can then, at his discretion, inform the Local Health Authority. When instructions are received from the Local Authority they should be carried out carefully and conscientiously, even though they impose restrictions upon the freedom of the individual, or appear to be unnecessarily officious, or even silly, to the citizen. The important fact to bear in mind is that the individual is not, in most cases, qualified to judge, and he rarely possesses the information that is at the disposal of the Local Authority.

During the months when carrion flies are about, all the food in the home should be carefully screened from flies. This screening is particularly important in the case of the family milk supply. Every endeavour should also be made to prevent the ingress of vermin into the storehouse and the home and to protect our food supplies from their depredations. An intensive and unremitting warfare should be waged against them

all over the country, especially in and around our docks, in the slum areas of our towns, and along our canals and sewers. There appears to be no reason why our Militia and our Civilian Defence Corps should not take an active part in this warfare. If the reasons for it were clearly explained to the units taking part, they would appreciate that it was work of great national importance and would co-operate willingly. A great reduction in the rat and rabbit populations of these islands would be a valuable asset to compensate for the cost and damage of war.

Special defensive measures are available for the individual and the community in the form of prophylactic inoculations against typhoid and paratyphoid fevers, cholera, and plague. Other measures are also available, and would be communicated to the population through the Local Health and Sanitary Services, if the need arose. For example, the wearing of a simple gauze, or linen, mask, which could easily be made at home, would give a large measure of individual protection against inhalation infection in areas known to be deliberately contaminated with anthrax spores. Bubonic plague depends for its start in a human community upon the intimate association of man, rat, and rat-flea. Where this association does not occur, or where it can effectively be prevented by individual and communal precautions, the human disease cannot become established. Even in areas where plague fleas are numerous, the wearing of leggings made of newspaper or brown paper will give considerable individual protection to individuals working in, or moving through the areas, because the flea cannot jump, or climb, above the leggings on to the clothing and body of the individual. Moreover, the widespread use of flake naphthalene will soon control any focus of plague fleas.

Apart from all these measures, the healthy human body possesses great powers of resistance to bacterial attack. The degree of resistance varies in the individual to the different species of human pathogenic bacteria, but on the whole it is sufficient to give a large measure of protection. It may be weakened by the strain and distress of war, although much can be done by the individual to maintain his or her resistance to bacterial attack in war-time. Avoidance of overcrowding, especially during epidemic times, moderation in the use of alcohol, avoidance of chilling and exposure as far as possible, the consumption of cooked foods and of boiled water and milk when necessary, and as much fresh air and judicious exercise

as are obtainable, are all valuable measures that the individual can take to conserve his bodily resistance. The refusal to heed and to spread rumours, a steadfast belief in the moral values for which he is fighting, diligent application to the work in hand, the eager pursuit of some hobby—especially during the long winter evenings—intelligent reading, and sufficient sleep, are measures that secure the possession of a quiet mind, without which the body cannot put up a successful resistance to bacterial attack.

In conclusion, while it is foolish to ignore the threat of bacterial warfare, or to underestimate its dangers, there is no need to fear it unnecessarily. In some ways it is much less to be feared than enemy attack on a civilian population with high explosive, gas, and incendiary bombs from the air. Few bacterial diseases cause agonizing pain—syphilis in its tertiary stage is the chief exception to this general rule—and few of them leave behind the awful disfigurements and crippling deformities caused by high-explosive bombs. In these respects, bacterial warfare can be considered as more humane than ordinary physical warfare. It is doubtful also whether bacterial warfare against a civilized people with good medical and sanitary services would be more effective than bombardment with high explosive, or than insidious propaganda of the peace-at-any-price kind.

EPILOGUE

By the time the reader has reached this page he may possibly be feeling somewhat depressed, or even alarmed. If he possesses one of those encyclopædias on medical matters, supplied to the citizen on *ridiculously advantageous terms* (the italics are mine) by one of our enterprising popular publishing houses, he may begin feverishly searching the lists of signs and symptoms to see from which bacterial disease he is now suffering. The fear of a disease is technically known as a phobia (pronounced foe-bee-er), and is the next worse complaint after the actual disease itself. Indeed, syphilophobia can wreck an individual's peace of mind and, indirectly, his health. This is a tragedy, because no adults need fear syphilis except those who deliberately go out of their way to acquire it.

The subject of human bacterial disease may tend, however, to

arouse phobias in those who lack the necessary knowledge and experience to be able to take a balanced view of the subject. The large number of bacterial diseases to which man is susceptible, their variety of form and progress, the multiplicity of ways by which they can be acquired, the ubiquity of the responsible germs, and the present failure of medical science to provide effective protection and treatment in many cases, combine to produce what may seem, at first sight, to be a gloomy prospect for the individual and for the race. These diseases are not, however, recent inflictions upon mankind. Some of them are almost as old as man himself; most of them have an origin that is lost in the mists of time. The human race is still flourishing in spite of the continuous attacks of pathogenic bacteria, and there is no evidence that it is likely to be exterminated in the immediate future.

I have deliberately emphasized in this book the power of certain germs to cause disease in man, because this power is enhanced by ignorance, indifference, and carelessness upon the part of the individual and the community. On the other hand, I have also emphasized that the healthy human body is naturally equipped with a remarkable capacity of resistance to bacterial attack. Throughout the life-time of each individual the body is successfully resisting unaided the attacks of various pathogenic germs, and the individual is blissfully unconscious of these attacks. If the implantation of a pathogenic bacterium in the human body were to be inevitably followed by recognizable disease, the lives of most human beings would be a succession of bacterial diseases from the cradle to the grave. It is impossible for the individual to ward off completely the attacks of pathogenic germs; yet how often, my reader, have you suffered from recognizable bacterial disease in the course of your life? Probably you had measles, chicken-pox, and whooping-cough as a child, of which only the last is a bacterial disease. You may also have had mumps and german measles, neither of which is a bacterial disease. Your recovery from these diseases has most probably conferred upon you a solid immunity that will protect you for the rest of your life from a second attack of any one of them. You may also have suffered from diphtheria and/or scarlet fever, unless your parents took the precaution to have you actively immunized against them before you started school, and again after you left school. You may even have had one or both of these diseases although you were actively im-

munized against them in early childhood. If this is the case, you may feel that you have a grievance against medical science, and be receptive to the propaganda that is pumped up from the wells of ignorance and misrepresentation by people who oppose vaccination and artificial immunization, because these human measures are not infallible and do not give an absolute, universal protection against the diseases for which they are employed. An artificially induced immunity can hardly be expected always to give solid protection from infancy to old age. When these measures fail in the individual, the explanation is either (*a*) that the soil is unsuitable—*i.e.*, the tissues of the individual are inherently incapable of responding properly to the stimulus, or (*b*) that the individual has out-grown the immunity conferred upon him in childhood and ought to have had the stimulus repeated during adolescence. Someone can always be found to oppose any beneficient human activity, and minorities are generally vociferous in inverse proportion to their knowledge of the subject upon which they disagree with the majority. There are still some individuals living in Great Britain who believe that the earth is flat! It is our loss, as a people with a sense of humour, that no Briton holding this belief has fallen off the edge and climbed back again to record his experiences in the columns of our sensational Press.

Apart from the bacterial diseases already mentioned, you will probably have had numerous colds, possibly several attacks of " influenza " and one or two of the real disease, probably a few boils, possibly a few " sore throats ", and a varying number of illnesses diagnosed as " catarrh ", " gastric flu ", " diarrhœa ", " colic ", or " congestion of the lungs." This list exhausts the recognized bacterial infections that assail a majority of the population up to late middle age, especially if minor septic infections of the skin are included. After the bacterial diseases of childhood, the two commonest infections in the British Isles are tuberculosis and pneumonia, but only a small percentage of unfortunate persons contracts tuberculosis, and pneumonia is relatively uncommon between the ages of 15 and 45. The Registrar-General's returns of the causes of death at all ages among the inhabitants of Great Britain show that heart disease and cancer head the mortality lists and then, but a long way after, come tuberculosis and pneumonia. In London there were 37,867 deaths registered in 1939 up to the end of October. Heart disease was responsible for 11,299 of these, cancer for

5,588, all forms of tuberculosis for 2,342, and pneumonias for 3,672. It is true that a certain number of the deaths from heart disease are the result of the action of bacterial toxins upon the heart, but, if these cases are excluded, heart disease that is not of bacterial causation still remains easily the commonest cause of death in the British Isles, because the figures for London apply with only slight alterations to the whole of Great Britain.

It is therefore evident that at all times the bacterial diseases of man that are endemic in our islands are pre-eminently casualty diseases. Individual infections are many, deaths are relatively few. The cost of these diseases to the nation is, however, colossal, and for this reason alone, quite apart from the huge volume of suffering and distress they cause, we ought to strive as individuals and citizens, by all means in our power, to reduce their incidence. Nelson's immortal signal at the battle of Trafalgar is as clear a call to us to-day in our fight against bacterial disease as it was to our ancestors in their fight against Napoleon. Our duty as individuals is to conserve our bodily and mental resistance by good living and clean thinking, to protect our children by careful up-bringing and the intelligent use of the preventive measures that medical science provides, and to take care that we do not spread any infection that we may have contracted among our fellow-countrymen.

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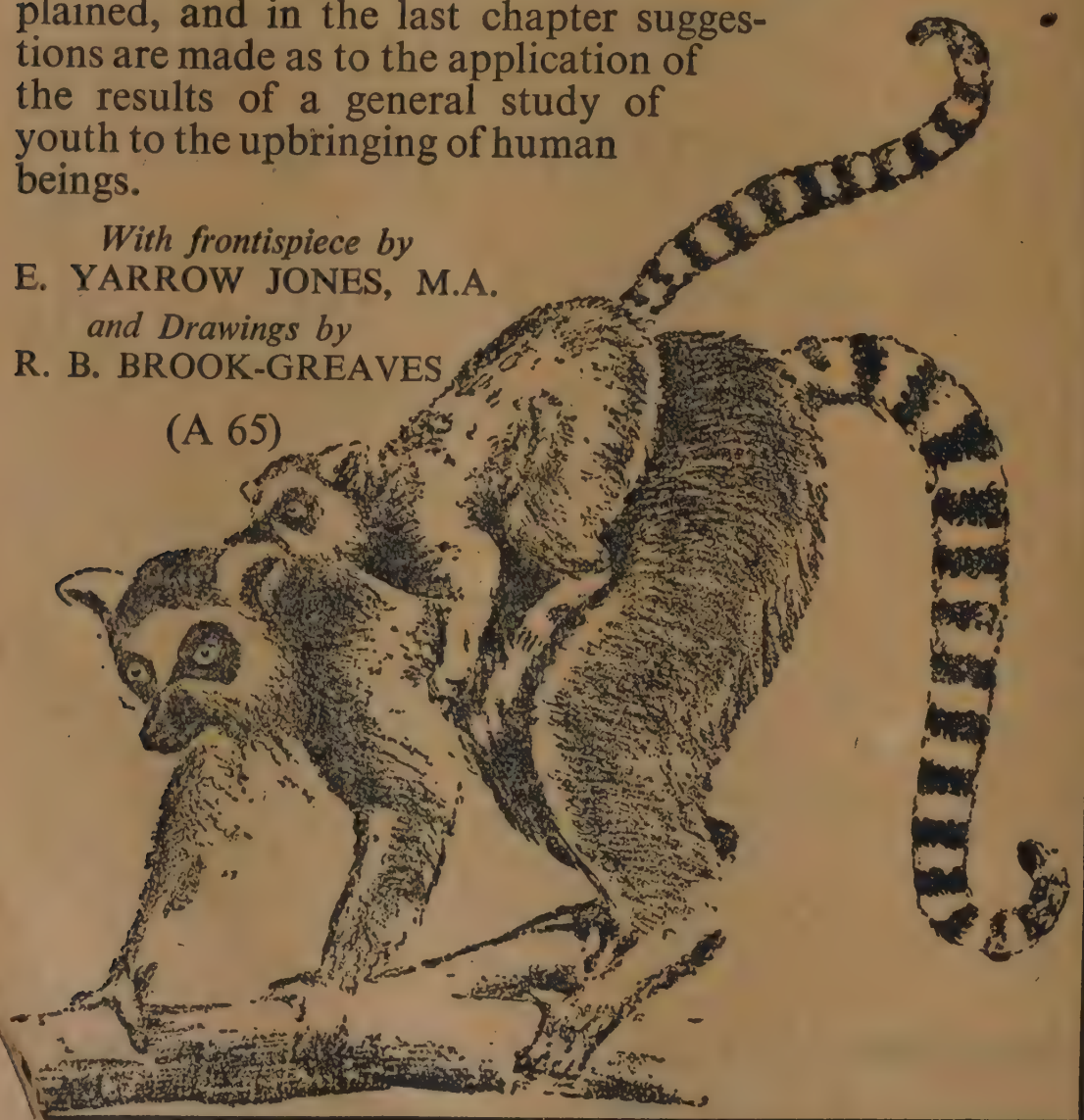
(A 65)



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